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# DESIGN PERFORMANCE STANDARDS

GOVDOC
BRA
3911

## WIND & AIR CIRCULATION
## SUNLIGHT & DAYLIGHT

**BOSTON REDEVELOPMENT AUTHORITY GRANT APPLICATION**

**Submitted to the**
**NATIONAL ENDOWMENT FOR THE ARTS**
**DESIGN EXPLORATION/RESEARCH: POLICY & DESIGN**

**December 1983**

Boston Redevelopment Authority
Robert J. Ryan, Director

# DESIGN PERFORMANCE STANDARDS

## WIND & AIR CIRCULATION
## SUNLIGHT & DAYLIGHT

**Boston**
**Redevelopment**
**Authority**

Robert J. Ryan/Director

December 20, 1983

National Endowment for the Arts
Grants Office/D.A.P.
2401 E Street, N.W.
Washington, DC 20506

Dear Sir/Madam:

Development activity in recent years has been beneficial for Boston's economy, but there is increasing concern in this city about the effects of new development on our quality of life, specifically the increased wind flow around tall buildings and the diminished light which reaches pedestrian areas.

We want Boston to maintain its economic vitality, and believe that the prevailing planning context that considers the impact of development on people can continue to direct Boston's future growth. We are a city built to pedestrian scale and it would undermine everything that's unique about Boston's distinctive character if development were to overwhelm our pedestrian network and our public open spaces.

Accordingly, we should establish written comprehensive design standards that take into account the relationship of buildings to the environment. Toward this end, I want to express my support for a grant application that would help us develop methods for reviewing and evaluating development proposals from a wind and light perspective.

It is most important that we do not fail to consider both the immediate economic benefits of new development along with the long-term impacts of these same projects. With this study, Boston has the opportunity to develop building standards that will benefit people today and in the future. Moreover, we may develop comprehensive standards and policies that will prove helpful to other cities.

Sincerely,

Robert J. Ryan
Director

B2/Z/121983

1 City Hall Square
Boston, Massachusetts 02201
(617) 722-4300

OMB-128-R-0001

# Design Arts Organization Grant Application Form NEA-3 (Rev.)

Three clear copies must be submitted to: Grants Office/DAP, National Endowment for the Arts, 1100 Pennsylvania Avenue, N.W., Washington, D.C. 20506

**I. Applicant Organization (name, address, zip)**

Boston Redevelopment Authority
One City Hall Square
Boston, MA 02201

**II. Category under which support is requested:**

☐ Design Demonstration
☒ Design Exploration/Research
☐ Design Communication

**III. Period of support requested:**

| | month | day | year |
|---|---|---|---|
| Starting | June | 1 | 1984 |
| Ending | May | 31 | 1985 |

**IV. Summary of project description (Complete in space provided. DO NOT reduce copy or continue on additional pages.)**
**TITLE (Please underline):**

Design Performance Standards for the Microclimate: Wind-Air Circulation/Sunlight-Daylight

For the past several years, development in Boston and other urban centers has been intensifying and transforming the urban topography as well as affecting its microclimate. This development has occurred without the benefit of design performance standards that are intended to avoid the generation of high winds and blocking of air flows that disperse pollutants and to preserve sunlight and daylight.

The Boston Redevelopment Authority is proposing to develop policies and performance standards for these microclimatic variables. A methodology for implementing these standards will be formulated that can be adapted to a variety of urban patterns as represented in Boston and to particular climatic conditions and policies in each city.

The first component of the proposal is to develop a state-of-the-art code for pedestrian level winds. Comfort criteria for different pedestrian areas and will be identified; current technology will be evaluated in terms of its adequacy to predict pedestrian level winds; a methodology for using wind technology that predicts the extended downwind influence of a structure will be developed.

The air circulation component will identify urban forms that generate micro-air inversions, concentrate air pollutants, or block beneficial prevailing or localized winds. Design standards and a methodology for predicting and avoiding these phenomena will be formulated. The wind and air flow components will be complementary since the wind element will emphasize the technology needed and the air flow urban form and illustrative principles.

The third element will develop methodology for determining the relative significance of sunshine and light in public spaces. Policies and a methodology for preserving light and daylight at the street level will be formulated. They will be based on an evaluation of the existing conditions and benefits of daylight, sun and shadow on pedestrian and open space areas and how light levels affect the use of the space and enjoyment of the city. Specific controls and their impact on design elements will be identified.

**V. Estimated number of persons expected to benefit from this project** 370,000

**VI. Summary of estimated costs (recapitulation of budget items in Section IX)**

| | | Total costs of project (rounded to nearest ten dollars) |
|---|---|---|
| A. Direct costs | | |
| Salaries and wages | | $ 17,420 |
| Fringe benefits | | 10,900 |
| Supplies and materials | | 5,500 |
| Travel | | |
| Permanent equipment | | |
| Fees and other | Consultants (includes BRA contract employee) | 40,500 |
| | Total direct costs | $ 74,320 |
| B. Indirect costs | | $ 8,240 |
| | Total project costs | $ 82,560 |

**VII. Total amount requested from the National Endowment for the Arts** $ 40,000

| VIII. Organization total fiscal activity | Most recently completed fiscal period | Estimated for current fiscal year |
|---|---|---|
| A. Expenses | 1. $ 14,300,000 | 2. $ 16,000,000 |
| B. Revenues, grants, & contributions | 1. $ 14,300,000 | 2. $ 16:000,000 |

Do not write in this space

## IX. Budget breakdown of summary of estimated costs

### A. Direct costs

#### 1. Salaries and wages

| Title and/or type of personnel | Number of personnel | Annual or average salary range | % of time devoted to this project | Amount $ |
|---|---|---|---|---|
| Key Personnel | | | | |
| Linda Bourque, Environmental Plng. Specialist | | $25,770 | 25% | 6440 |
| Sandra Fein-Swaile, Architect IV | | 22,187 | 15% | 3330 |
| Gregory Perkins, Economic Analyst | | 23,426 | 10% | 2300 |
| Victor Karen, Senior Architect | | 23,500 | 10% | 2350 |
| Administrative Review | | | | |
| Susan Allen, Dep. Dir of Environmental Policy | | Average | | |
| Richard Mertens, Environmental Review Officer | | 30,000 | 5% | 1500 |
| Pamela Wessling, Dev. Policy Coordinator | | | | |
| Supporting Design and Graphics Staff | | 21,500 | 7% | 1500 |

Total salaries and wages $ 17,420

Add fringe benefits $ 10,900

Total salaries and wages including fringe benefits $ 28,320

#### 2. Supplies and materials (list each major type separately)

| | Amount $ |
|---|---|
| Mapping and Graphics Materials | 500 |
| Reproduction of Graphics | 1500 |
| Publication | 3000 |
| Photographic Supplies and Processing | 500 |

Total supplies and materials $ 5500

#### 3. Travel

**Transportation of personnel**

| No. of travelers | from | to | Amount $ |
|---|---|---|---|

Total transportation of personnel $

**Subsistence**

| No. of travelers | No. of days | Daily rate | $ |
|---|---|---|---|

Total subsistence $

Total travel $

**IX. Budget breakdown of summary of estimated costs (continued)**

**4. Permanent equipment** Amount

$

Total permanent equipment $ ________

**5. Fees for services and other expenses (list each item separately)** Amount

| | | |
|---|---|---|
| Consultant Services | | $ |
| Barbara Barros, Urban Designer | 20% | |
| BRA Contract Employee (BRA Share) | $30,000 | 6,000 |
| Frank Durgin, Engineer - Wind Consultant | | 11,500 |
| Ann Spirn, Urban Designer - Wind Air Flow Consultant | | 11,500 |
| Harvey Bryan, Architect - Sunlight Daylight Consultant | | 11,500 |

Total fees and other $ 40,500

**B. Indirect costs** *Actual indirect calculated monthly in accordance with A-102

Rate established by attached rate negotiation agreement with National Endowment for the Arts or another Federal agency

Amount

Rate 24 % Base $ 34,320 $ 8,240

**X. Contributions, grants, and revenues (for this project)** Amount

**A. Contributions**

**1. Cash**

$

**2. In-kind contributions (list each major item)**

Total contributions $ ________

**B. Grants (do not list anticipated grant from the Arts Endowment)**

$

Total grants $ ________

**C. Revenues**

Total revenues $ ________

Total contributions, grants, and revenues for this project $ ________

## XI. State Arts Agency notification

The National Endowment for the Arts urges you to inform your State Arts Agency of the fact that you are submitting this application.

Have you done so? X yes ______ no

## XII. Certification

We certify that the information contained in this application, including all attachments and supporting materials, is true and correct to the best of our knowledge.

**Authorizing official(s)**

Signature x ______ Date signed December 20, 1983
Name (print or type) Robert J. Ryan
Title (print or type) Director
Telephone (area code) (617) 722-4300, X201

Signature x Susan Allen Date signed ______
Name (print or type) Susan Allen
Title (print or type) Deputy Director for Development Policy
Telephone (area code) (617) 722-4300, X288

**Project director**

Signature x Linda S. Bourque Date signed December 20, 1983
Name (print or type) Linda S. Bourque
Title (print or type) Environmental Planning Specialist
Telephone (area code) (617) 722-4300, X308

***Payee (to whom grant payments will be sent if other than authorizing official)**

Signature x Joseph J. Noonan Date signed December 20, 1983
Name (print or type) Joseph J. Noonan
Title (print or type) Controller
Telephone (area code) (617) 722-4300, X360

*If payment is to be made to anyone other than the grantee, it is understood that the *grantee* is financially, administratively, and programmatically responsible for all aspects of the grant and that all reports must be submitted through the grantee.

**BE SURE TO DOUBLE CHECK THE "HOW TO APPLY" SECTION ON PAGE 17 AND THE SPECIAL APPLICATON REQUIREMENTS FOR YOUR CATEGORY FOR ALL MATERIALS TO BE INCLUDED IN YOUR APPLICATION PACKAGE. INCOMPLETE APPLICATIONS WILL BE JEOPARDIZED IN THE REVIEW PROCESS.**

**Privacy Act**

The Privacy Act of 1974 requires us to furnish you with the following information:

The Endowment is authorized to solicit the requested information by Section 5 of the National Foundation on the Arts and the Humanities Act of 1965, as amended. The information is used for grant processing, statistical research, analysis of trends, and for congressional oversight hearings. Failure to provide the requested information could result in rejection of your application.

GOVDOC
BRA
3911

# DESIGN PERFORMANCE STANDARDS

## WIND & AIR CIRCULATION
## SUNLIGHT & DAYLIGHT

### WORK PROGRAM

BOSTON REDEVELOPMENT AUTHORITY GRANT APPLICATION

Submitted to the
NATIONAL ENDOWMENT FOR THE ARTS
DESIGN EXPLORATION|RESEARCH : POLICY & DESIGN

December 1983

Boston Redevelopment Authority
Robert J. Ryan, Director

CITY OF BOSTON • MASSACHUSETTS

OFFICE OF THE MAYOR
RAYMOND L. FLYNN

January 30, 1984

Mr. Michael J. Pittas, Director
Design Arts Program
National Endowment for the Arts
Grants Office/D.A.P.
2401 E Street, N.W.
Washington, D.C. 20506

Dear Mr. Pittas:

All too often it is asssumed that development in our urban centers - and its immediate impact on our environment - is a price we must pay for economic growth. It is my belief that we can have economic expansion in our cities, but that careful and thoughtful planning can enhance, not diminish, our quality of life. The planning I'm referring to takes into consideration the issues of wind, air circulation and light, all those factors which should be studied when new development is proposed.

However, it is also clear that more technical work must be done in developing methods and procedures to improve our understanding of the relationship between the built environment and the people of our cities. That's why I enthusiastically endorse the Boston Redevelopment Authority's grant application to develop design performance standards which focus on climate factors in urban design. This study should yield the technical data our planners need to apply new design review process in Boston and our work will undoubtedly be of use to many other cities in the years ahead.

Sincerely,

Raymond L. Flynn

Raymond L. Flynn
Mayor

RLF/jd

BOSTON CITY HALL • ONE CITY HALL PLAZA • BOSTON • MASSACHUSETTS 02201 • 617/725-4000

## PROJECT CONTEXT

The Boston Redevelopment Authority has recently completed two phases of a three-phase project aimed at developing guidelines for managing future growth and development in the City. The first phase, culminated by the 1983 publication of "Issues of Development" and "Background on Development", documented the City's recent economic, demographic, and physical changes; forecast its economic and physical growth for the next decade; and, given these trends and projections, outlined the development issues facing Boston. The second phase proposed general policies and will serve as the framework for writing detailed development guidelines and regulations - the third phase of the project. The policies encompass public environment issues including community character, public safety, health and comfort, and access; housing development; energy and infrastructure; economic development. In order to progress from the policies to design guidelines, specific programs, and ordinances or zoning code changes to implement policies, a set of three urban design studies are being planned: density and capacity; district character; and, microclimate. These studies will be undertaken concurrently in order to coordinate findings and resulting implementation programs.

For carrying out these three studies, several districts will be defined for Central Boston based on their distinct character and predominant urban form. Boston has a wide variety of urban patterns from the grids of the Back Bay and the Bulfinch Triangle to the radial maze-like patterns of the Central Business District. Five of these areas have been outlined in Figure 1. Each of these districts will have a District Advisory Group composed of local businesspersons and community representatives. It is anticipated, however, that this planning process will be extended to other districts and neighborhoods in Boston. A strong economic base has been established in downtown Boston, and there is now a growing interest in promoting development outside of the core and into other underutilized areas where these guidelines will be essential.

The National Endowment for the Arts Grant for which the BRA has applied would provide the technical expertise critical to developing design performance standards for the microclimate portion of this study. The guidelines and standards that are developed as well as the methodology used in this study will be able to be adapted by other cities to implement microclimate performance standards based on their own policies and goals. The great diversity throughout Boston in terms of street patterns, architectural style, massing, scale, and density make this an excellent city in which to develop and test microclimate standards that can be applied to other cities.

The microclimate guidelines will be a major element in implementing the City's following policy statements or goals which are based on the concept that it is the public purpose that Central Boston be fit for people who use it, allowing them to conduct their activities in safety and in good health and comfort. The microclimate elements that are most affected by and affect development in terms of building form and massing are wind, air circulation and pollution, sunlight and daylight.

- Ensure sunlight in public ways and spaces, and adequate daylight and frequent views of the sky along most city streets.

- Prevent heavy and dangerous winds in public areas, but ensure that prevailing winds and sea breezes are not blocked.
- Reduce air pollution, particularly that generated by vehicular traffic and construction.
- Enhance existing open spaces and create new ones.
- Ensure that public ways and open spaces are safe.

## PURPOSE

The specific goals of this proposed microclimate study are to:

- develop wind and air circulation/pollution performance standards for the design, massing, and location of buildings as they affect the comfort, health, safety and sense of well being of people using the city streets and open spaces.
- identify the existing qualities of sunlight, daylight and visible sky in public open space and streets, the use of this space, and how the sunlight conditions affect that use; develop sunlight and daylight performance standards for buildings as they affect comfort and sense of well being of people using the city streets, and open space areas.

The guidelines and standards are not intended to impose rigid controls on architectural design, but rather to provide a context in which development can take place while still maintaining a humanistic scale in the City and a safe hospitable environment for resident and visitors. It is, therefore, important that the microclimate standards are developed early in the process of defining guidelines for the overall Boston development policies study. In order to maintain a positive quality of life in the City, succeeding development guidelines should respond to these basic goals.

The study has been divided into the three major areas of wind, air circulation and pollution, and sunlight and daylight. However, these elements are interrelated, and the final step in the process will be to coordinate findings and performance standards.

We have selected three consultants to work with us on this study who we feel can offer the highest level of expertise in their respective fields, and who understand the urban environment and intricacies of relating microclimate variables to urban design.

Frank Durgin, who will be responsible for the wind analysis, is currently Associate Director of the Wright Brother's Wind Tunnel at the Massachusetts Institute of Technology. He has been involved in the field of aerodynamics and building structures for over twenty years and has made significant advances in the state-of-the-art of wind tunnel testing. Mr. Durgin conducted the wind tunnel analyses for the comprehensive downtown Dayton, Ohio study.

Anne Whiston Spirn, who will be conducting the air circulation and air pollution element of the study, is an Associate Professor of Landscape Architecture at Harvard University Graduate School of Design. She has written the recently-published book The Granite Garden: Urban Nature and Human Design which deals with air pollution, climate and design in the urban setting. She also worked with Frank Durgin on the Dayton Study.

Harvey Bryan, who will be developing the sunlight/daylight element of the study, is an Assistant Professor in the Department of Architecture at the Massachusetts Institute of Technology. He has conducted extensive studies in urban sunlight and daylighting design and in energy conservation, and was a consultant to the "Midtown Manhattan Development Project: Zoning Regulation Study" on daylight.

## WORK PROGRAM

### Phase I - MICROCLIMATE ANALYSIS AND GENERATION OF PERFORMANCE STANDARDS

### Sunlight and Daylight

Sunlight is key to th use of public ways and spaces. Guidelines and standards will be based on seasonal and diurnal use of public areas as well as on the actual type of use, size and situation of public spaces. Ensuring the presence of sunlight along all of the narrow, winding streets of Boston, although desirable, would not be practical. However, it is important to maintain adequate daylight and views of the sky on city streets.

Step 1: The first step of this analysis will be to review the historical background of sunlight/daylight standards and different approaches and methodologies for managing this urban design issue made by cities in the United States, Europe and England. This review will provide a perspective on the appropriateness of certain methodologies and a basis to advance the state-of-the-art.

Step 2: In this step we will conduct an inventory of sunlight, daylight and sky view on streets, open spaces, and building facades in each of the study districts.

- o utilize full-field camera survey of locations and analyze sky exposure dome.
- o map existing sunlight and daylight exposure.

Step 3: The current and potential use of city streets and spaces in terms of intensity and times of day/year will be analyzed, as well as the significance of sunlight on spaces.

- o District Advisory Groups and BRA professional staff will be consulted to define positive characteristics of each district and problem areas.
- o areas where sunlight should be preserved and varying degrees of significance of sunlight to each district will be mapped.

Step 4: Performance standards and methodology for measuring amount of sunlight and daylight which will result from different project proposals will be developed.

- performance standards will be tested on specific sites for potential or current development proposals.

## Wind Analysis

Boston is one of the windiest cities in the country, and the effects of its strong winds are made worse in locations where tall buildings deflect winds and create gale force gusts at street level. Moreover, dense concentrations of large buildings can create narrow streets into canyons which trap air pollutants at the pedestrian level.

Step 1: The first step of this analysis will review wind tunnel techniques and methodologies for analysis in order to determine the most appropriate and best predictive state-of-the-art technology.

- establish technological criteria for wind tunnel simulation.
- determine what the wind tunnel should measure and in what form the data should be.
- establish uniform weather data to be used in wind tunnel simulation.

Step 2: Determine specific comfort criteria and acceptable wind levels for a specified percentage of time in different types of pedestrian areas.

- review Melbourne wind comfort criteria to relate their to applicability to Boston climatic regime.

Step 3: Establish specific standards to be used in requiring wind analyses.

- establish criteria for determining when wind tunnel simulation is necessary.
- recommend quality control measures for simulated data.
- establish reference spots throughout Central Boston for comparison and standardization of wind analyses.

Step 4: Propose further analyses that would promote incorporation of new and improved techniques as this relatively young science advances.

## Air Circulation and Air Pollution at the Pedestrian Level

In Boston, as well as other older urban centers, vehicular traffic presents the worst air pollution problem for the pedestrian. A body of literature on transportation-related air pollution at the street level and on air circulation within urban street canyons exists. To date, however, it has had little or no

impact upon how cities guide development in the urban core. This analysis will assess current data and demonstrate how cities, using Boston as a case study, can predict zones of high pollution concentrations at the pedestrian level, and how they might guide urban form to enhance dispersion of pollutants and limit pedestrian exposure to unhealthy pollutants.

Step 1: This first step will be to review and update the literature on transportation-related air pollution at the pedestrian level since 1979.

- o analyze carbon monoxide data collected in the City to determine patterns of concentrations and sources.

Step 2: Identify major factors influencing air quality at the street level.

- o identify major pollutants and acceptable concentrations to protect public health.
- o identify sources of pollutants including vehicular traffic, parking garages, potential stack downdraft phenomena.
- o analyze forces of dispersion and concentration of pollutants as related to urban form.
  - micro-inversions in street canyons
  - onshore and offshore sea breezes
- o identify potential air pollution sinks such as trees and vegetated areas.

Step 3: Formulate criteria for predicting potential zones of high air pollution at pedestrian level both within existing urban form and as influenced by new building proposals.

- o analyze impact of criteria on development.

Step 4: Relate criteria to wind and sunlight/daylight studies.

- o wind tunnel "erosion" studies for a proposed building indicate where reduced air circulation will result.

Step 5: Formulate design and planning guidelines to reduce pedestrian exposure to air pollution.

Step 6: Demonstrate, test, and refine criteria and design strategies through their application to at least one planning district within Central Boston.

Step 7: Recommend further works and areas of future research by Boston which would yield important results in understanding the relation between urban form and air quality at the pedestrian level.

MS3/U/013184

## Phase II - INTEGRATION OF PERFORMANCE STANDARDS AND ANALYSIS OF IMPACT ON DEVELOPMENT

Step 1: Integrate wind, air circulation and air pollution, and sunlight/daylight criteria and performance standards.

Step 2: Test performance standards on one or more specific development sites to demonstrate the impact on overall building form and massing and appropriatness of the methodology used.

Step 3: Analyze the impact of performance standards on potential development within the City of Boston.

## Phase III - IMPLEMENTATION OF PERFORMANCE STANDARDS

Step 1: Prepare report, slide presentation of study.

Step 2: Recommend specific sunlight/daylight, wind, air circulation/pollution performance standards and implementation procedures.

## Phase IV - PUBLIC REVIEW AND ADOPTION OF PERFORMANCE STANDARDS Post Grant

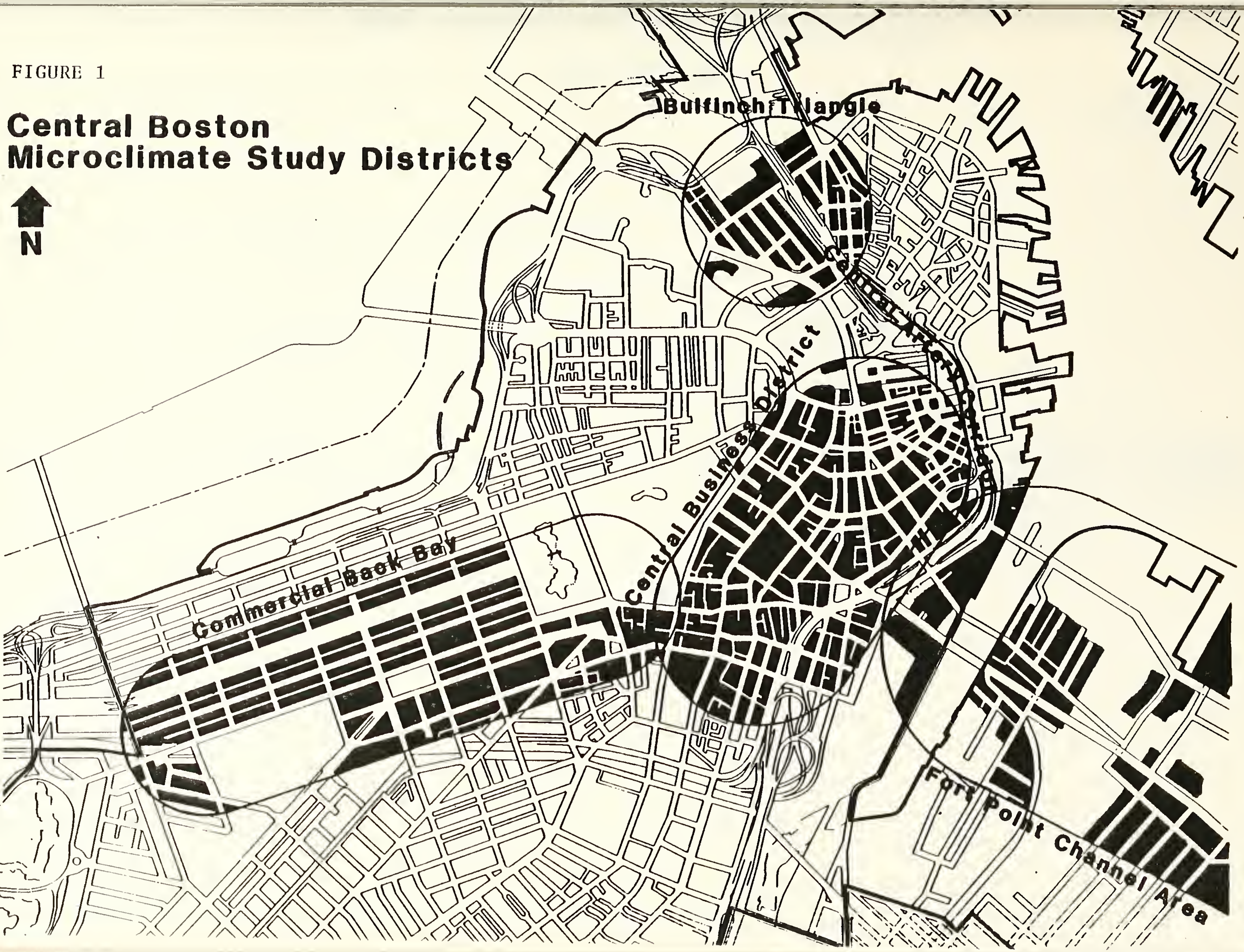
Step 1: Present microclimate standards with other development guidelines for public review.

Step 2: Adoption of standards by Boston Redevelopment Authority Board.

Step 3: Implement appropriate zoning code, building code, and City ordinance changes.

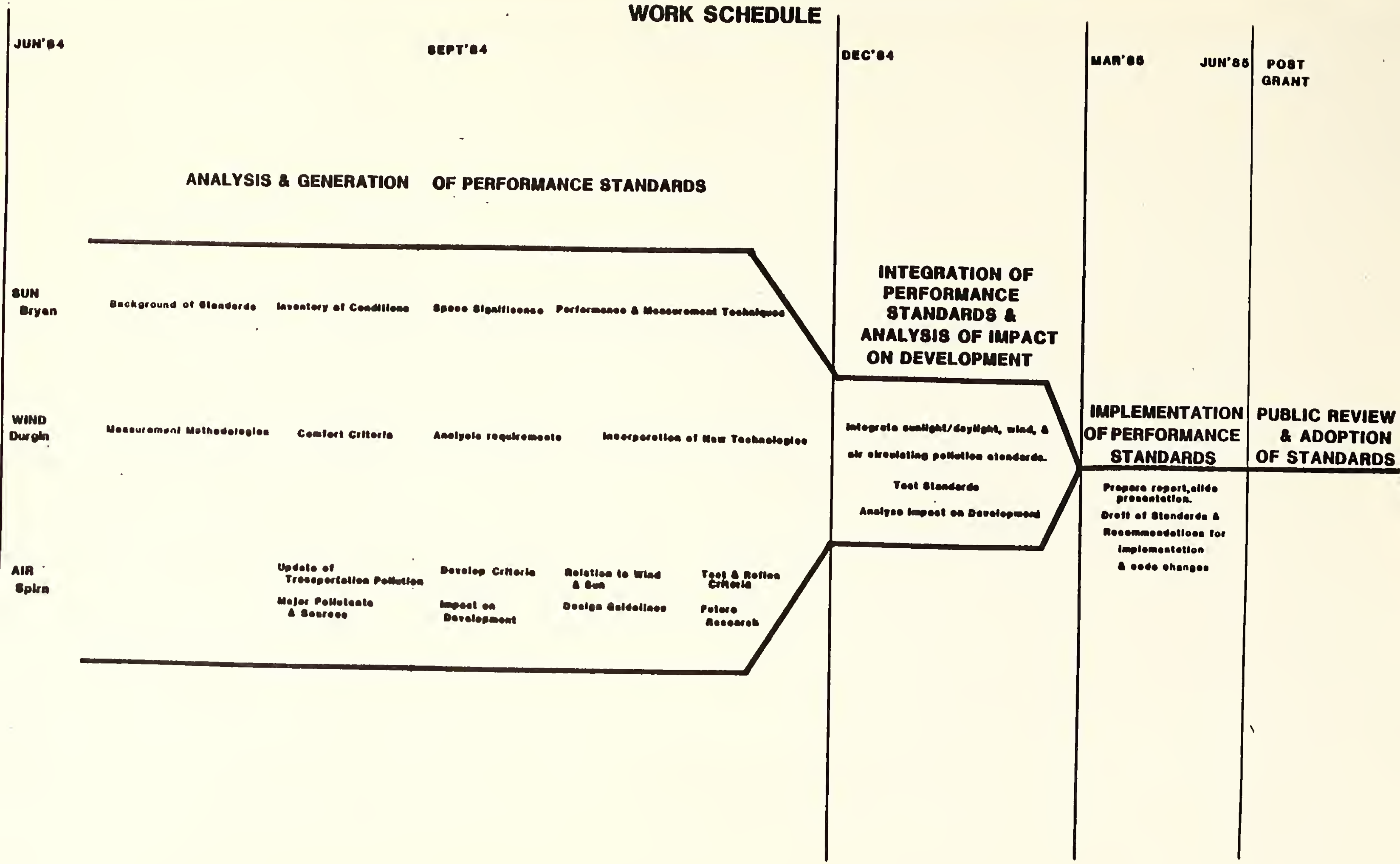
FIGURE 1

## Central Boston Microclimate Study Districts



# DESIGN PERFORMANCE STANDARDS FOR THE MICROCLIMATE

## WORK SCHEDULE


JUN'84
SEPT'84
DEC'84
MAR'85
JUN'85
POST GRANT
ANALYSIS & GENERATION OF PERFORMANCE STANDARDS
SUN
Bryan
Background of Standards
Inventory of Conditions
Space Significance
Performance & Measurement Techniques
WIND
Durgin
Measurement Methodologies
Comfort Criteria
Analysis requirements
Incorporation of New Technologies
AIR
Spirn
Update of Transportation Pollution
Major Pollutants & Sources
Develop Criteria
Impact on Development
Relation to Wind & Sun
Design Guidelines
Test & Refine Criteria
Future Research
INTEGRATION OF PERFORMANCE STANDARDS & ANALYSIS OF IMPACT ON DEVELOPMENT
Integrate sunlight/daylight, wind, & air circulating pollution standards.
Test Standards
Analyse Impact on Development
IMPLEMENTATION OF PERFORMANCE STANDARDS
Prepare report, slide presentation.
Draft of Standards & Recommendations for implementation & code changes
PUBLIC REVIEW & ADOPTION OF STANDARDS

X Grover

# DESIGN PERFORMANCE STANDARDS

## WIND & AIR CIRCULATION
## SUNLIGHT & DAYLIGHT

RESUMES
LETTERS OF SUPPORT
IRS DETERMINATION LETTER
ASSURANCE COMPLIANCE

**BOSTON REDEVELOPMENT AUTHORITY GRANT APPLICATION**

Submitted to the
NATIONAL ENDOWMENT FOR THE ARTS
DESIGN EXPLORATION/RESEARCH: POLICY & DESIGN

December 1983

Boston Redevelopment Authority
Robert J. Ryan, Director

*The Commonwealth of Massachusetts*
*Executive Office of Environmental Affairs*
*100 Cambridge Street*
*Boston, Massachusetts 02202*

MICHAEL S. DUKAKIS
GOVERNOR

JAMES S. HOYTE
SECRETARY

December 14, 1983

National Endowment for the Arts
Grants Office/D.A.P.
2401 E Street, N.W.
Washington, D.C. 20506

Dear Sirs:

I support the application by the Boston Redevelopment Authority for a grant to develop design performance guidelines for urban wind problems and access to sunlight and daylight at the pedestrian level.

During the past few years, members of my staff have worked closely with the BRA to evaluate the effects of major development projects in downtown Boston on the pedestrian environment. Thus, I am familiar not only with the problems to be dealt with in the study, but also with the BRA's ongoing efforts to resolve them.

Boston's reputation as a windy city is well deserved, and some of its wind problems - for example, those experienced at Hancock Tower - are well known. Less well known is the fact that wind effects on the pedestrian environment are often a determining factor in the commercial viability of major development projects. Although wind technology is a relatively new field, a substantial body of tested knowledge on the subject does exist. Given the large number of people living and working in the city who experience the impacts of pedestrian level winds, it is very important to package the available information in a manner which allows it to be readily grasped and put into practice by those who need it: community officials, reviewing agencies, architects and developers.

Although Boston is fortunate in having an attractive, sunny pedestrian environment, as the City grows, this becomes more difficult to preserve. Therefore, it is important that these conditions be preserved through the application of sound design standards.

The grant application to study these issues has my strong support. My staff and I hope to be among its beneficiaries.

Sincerely,

JAMES S. HOYTE, Secretary

JSH/SGM/dc

James L. Sullivan
*President*

Greater Boston
Chamber of Commerce
125 High Street
Boston, MA 02110
Tel: 426-1250

December 13, 1983

Grants Offices/D.A.P.
National Endowment for the Arts
2401 E Street, N.W.
Washington, D.C. 20506

Dear Program Officer:

On behalf of the Greater Boston Chamber of Commerce, I would like to express our support for an application submitted by the City of Boston to the National Endowment for the Arts which seeks to undertake a study of the environmental impacts of high-rise buildings on the downtown and neighborhoods. This study, along with the establishment of performance standards, will ensure that City growth plans, as well as proposals from the development community, are sensitive to such environmental concerns as wind, light and shadow and the pedestrian orientation of this City.

The City of Boston's grant application is of particular import, at present, as the downtown core is experiencing unprecedented growth. The proposed study will enable both the public and private sector's to positively shape Boston's physical change, while at the same time address those quality of life issues of continued concern to area residents and businesses.

For over three years, the Chamber's BOSTON 2000 project has brought together the City government, planning and design professionals, businesses and community groups to identify short and long-range physical growth concerns. Through our "Development Guidance Project" we are specifically seeking to address urban design concerns. Again, the City's proposal to N.E.A. is both timely and a critical piece in terms of public/private and community efforts to establish development policies and criteria which will ensure Boston's economic and physical vitality.

We urge the National Endowment of the Arts to act favorably upon the City of Boston's grant request.

Sincerely,

James L. Sullivan
President

JLS/sa

BSA

**A. Anthony Tappé, FAIA**
President

20 December 1983

Ms. Marguerite Villecco
National Endowment for the Arts
Design Arts Program
2401 E. Street, N.W.
Washington, D.C. 20506

Re: Boston Redevelopment Authority
Design Performance Standards for the Microclimate
Matching Grant Application

Dear Ms. Villecco:

This is to indicate support by the Urban Design Committee of the Boston Society of Architects for the application of the BRA for a grant to research the ways in which architecture influences wind, sunlight, and daylight conditions for pedestrians in the city. This information will be used in the process to define development policy and design guidelines - a process in which the BSA participates and fully supports. Like other cities under intense high rise development pressure in a dense urban environment, Boston experiences unpleasant wind and air quality situations and is gradually losing the daylight and sunlight which makes its ways and spaces pleasant.

Our committee of the BSA has long been concerned with the problems of wind, sunlight, and daylight caused by development. The BRA application appears to us to be a serious effort. The consultants proposed are known to us as expert in their disciplines, and we understand that the products of this effort will be available for public use.

We urge the NEA to give careful consideration to the application. We believe the work to be produced has merit and represents a forward-looking step with strong potential benefits to many cities and professionals concerned with the urban environment.

Yours sincerely,

Todd Lee

Todd Lee AIA
Commissioner of Design
Boston Society of Architects

TL:ww
cc: Thomas Payette - President, BSA
Lowell Erickson - Executive Director, BSA

The Boston Society of Architects

320 Newbury Street
Boston, Massachusetts 02115
Telephone 617 267-5175

A Chapter of
the American Institute
of Architects

# CONSULTANT RESUMES

ANNE WHISTON SPIRN

Department of Landscape Architecture 617-495-4341
Graduate School of Design
Harvard University
409 Gund Hall
Cambridge, MA 02138

BORN June 19, 1947

## EDUCATION

University of Pennsylvania, M. Landscape Architecture, 1974
University of Pennsylvania, Department of Art History, 1969-1970
Radcliffe College, Harvard University, B.A. 1969

## HONORS AND AWARDS

| | |
|---|---|
| 1981 | Project Fellowship, National Endowment for the Arts |
| 1978-1979 | Bunting Fellowship, Bunting Institute, Radcliffe College |
| 1974 | Special Award for Contribution to a Better Environment, American Society of Landscape Architects |
| | Special Mention, U.S. Department of Housing and Urban Development |
| | Both 1974 awards to Wallace McHarg Roberts and Todd for Woodlands New Community |

## ACADEMIC EXPERIENCE

| | |
|---|---|
| 1983- | Associate Professor of Landscape Architecture, Graduate School of Design, Harvard University |
| 1979-1983 | Assistant Professor of Landscape Architecture, Graduate School of Design, Harvard University |
| 1974-1976 | Guest Critic in Landscape Architecture, Graduate School of Fine Arts, University of Pennsylvania |

## ACADEMIC PUBLICATIONS

The Granite Garden: Urban Nature and Human Design.
New York: Basic Books, 1984.

Plants for Passive Cooling: A Preliminary Investigation.
Cambridge, Mass: Harvard Graduate School of Design, Spring 1981.

"Using Vegetation to Cool Small Structures,"
Proceedings of the 1981 Annual Meeting, American Section of the International Solar Energy Society: 906-910.

"The Role of Natural Processes in the Design of Cities."
The Annals of the American Academy of Political and Social Science 451 (September, 1980): 98-105.

## RESEARCH

Principal Investigator, grant from Oak Ridge National Laboratory, U.S. Department of Energy to study the use of vegetation for passive cooling of small structures,
Harvard Graduate School of Design, 1980-81.

Research Fellow, National Endowment for the Arts Project fellowship to document case studies of urban design adapted to the natural environment, 1981-82.

Research Consultant on grant awarded by the National Endowment for the Arts to the City of Dayton for Dayton Climate Project, 1981.

Research Fellow, Bunting Institute, to study the urban natural environment and its implications for urban form, 1978-79.

## PROFESSIONAL EXPERIENCE

| | |
|---|---|
| 1977-1978 | Landscape Architect and Environmental Planner,<br>Roy Mann Associates, Cambridge, Massachusetts |
| 1973-1977 | Landscape Architect and Environmental Planner,<br>Wallace McHarg Roberts and Todd, Philadelphia, Pennsylvania |
| | Project Director, Site Planning Guidelines for Woodlands New Community, Conroe, Texas |
| | Project Director, General Plan Revision for Woodlands New Community, Conroe, Texas |
| | Project Director, Slate Post Farm Master Plan, Northampton County, Pennsylvania |
| | Assistant Project Director, Pardisan Environmental Park and Zoo, Tehran, Iran |
| | Principal Planner, City of Sanibel Comprehensive Plan, Sanibel, Florida |

## PROFESSIONAL PUBLICATIONS

Resources of the Toronto Central Waterfront, co-author with Narendra Juneja, Wallace McHarg Roberts and Todd, 1976

Pardisan: An Environmental Park, co-author with Ian McHarg, Narendra Juneja, and W. Robinson Fisher, Wallace McHarg Roberts and Todd, 1973

Woodlands New Community: Guidelines for Site Planning, Wallace McHarg Roberts and Todd, 1973

## PROFESSIONAL REGISTRATION

Registered Landscape Architect by CLARB Examination
Commonwealth of Massachusetts #603

## CONFERENCES AND PUBLIC LECTURES

Moderator, Panel on Urban Nature and Human Design, American Society of Landscape Architects Annual Meeting, 1981

"Urban Design to Improve Air Quality and Climate," American Society of Landscape Architects Annual Meeting, 1981

"The Potential of Plants to Cool Small Structures: Pros and Cons," Oak Ridge National Laboratory, 1980

"The Urban Natural Environment: Problems of the Literature," Council of Educators in Landscape Architecture (CELA) Annual Meeting, 1980

"What is a Natural Drainage System: Woodlands, A Case Study," School of Architecture, City College of New York, 1983; University of Massachusetts, 1980; Boston Architectural Center, 1978; Department of Landscape Architecture, University of Wisconsin, 1976

"Historic and Scientific Perspectives on Nature in the City," Boston Urban Gardeners Open Space Conference, 1980

"City Plantings: An Environmental Rationale for Downtown Dayton," Dayton, Ohio, 1979

"Landscape Architecture: An Applied Art," Detroit Art Institute, Detroit, Michigan, 1979

Nature in the City: Implications for Urban Design," Bunting Institute Symposium, Cambridge, Massachusetts, 1979

"Mundane and Cosmic Applications of the Ecological Approach to Design," Department of Landscape Architecture, Harvard University, 1976, 1978; Department of Landscape Architecture, University of Wisconsin, 1976

"Social and Physical Determinants of Change in an Urban Neighborhood: Powelton Village, A Case Study," Department of Landscape Architecture, University of Pennsylvania, 1974, 1975, 1976, 1977; Department of Architecture, Temple University, 1974

"Applying Ecology to Landscape Design," The Garden Club Federation of Massachusetts, Landscape Design School, 1977

"Pardisan: A Novel Approach to Zoo Design," Department of Landscape Architecture, North Carolina State University, 1975

"History of Women in the Design Professions," Philadelphia Chapter, American Institute of Architects, 1974

## SERVICE ACTIVITIES

Department of Landscape Architecture Committees

Department of Architecture, Landscape Architecture Department Representative, 1981-1983

Graduate School of Design Committees:

- Academic Policy Committee, Landscape Architecture Department representative, 1980-83; Chairman, 1981-83.
- Landscape Architecture Department Chairman Search Committee, Landscape Architecture faculty representative, 1980-81.
- Special Programs Council, Lectures and Exhibits Subcommittee, 1980-81
- Library Committee, 1979-80
- Review of MBTA Harvard Square Project, 1980-81

Harvard University Committees:

- Historical Review Committee, 1983-
- President's Advisory Committee on the Status of Women at Harvard, Graduate School of Design representative, 1982-

Council of Educators in Landscape Architecture (CELA):

- Harvard representative at annual meeting in Madison, Wisconsin, 1980
- Journal Committee, 1980-81

Selection Committee, Bunting Institute, Radcliffe College, 1980-81

Consultant, Boston Urban Gardeners, for Massachusetts Council on the Humanities Grant to study urban open space, 1979-80.

## CURRENT COURSES

Advanced Project Planning and Design Studio (Fall) Coordinator. This studio is required of all second year students in landscape architecture. The course explores a range of site design problems at the project scale including design of housing and parks in urban and rural settings, and addresses underlying social and environmental issues.

Urban Open Space Studio (Spring). This is an optional studio for third year students. The course examines potential roles of urban open space. The perception of nature in the city, its symbolic meaning, historic assocations, and social and environmental functions are explored in a series of design projects from the mundane to the monumental.

City and Nature: Natural Process, Human Purpose, and Urban Form (Spring). This lecture course provides an introduction to the natural environment of cities, the interaction between natural processes and human values, and the relationship of that interaction to urban design. Urban climate, geology, hydrology, soils, vegetation, and wildlife are reviewed in the context of historic and current case studies.

Supervision of Independent Projects.(3-5 students per semester). Independent studio courses have included, among others: The Dayton Climate Project Studio; A Master Plan for Tourism at the Sardis Archeological Site in Turkey.

Independent courses have included, among others: Settlement Form and Landscape Change in Antiquity; The Aesthetics and Design Potential of Selected New England Plant Communities; Drought-Tolerant Landscapes for Semi-arid Climates.

RESUME: Harvey J. Bryan

## Personal Data

Born 8 September, 1948 in New York City.

## Education

Ph.D., Candidate, University of California, Berkeley, presently.
M.S., University of California, Berkeley, 1979.
M.Arch., University of California, Berkeley, 1974.
B.Arch., Arizona State University, Tempe, 1973.

## Academic Appointments

Assistant Professor, Department of Architecture, Massachusetts Institute of Technology, Cambridge, MA, 1980-present.
Adjunct Assistant Professor, School of Architecture, Rensselaer Polytechnic Institute, Troy, NY, 1980 (Spring).
Teaching Associate, Department of Architecture, University of California, Berkeley, 1976-1979.

## Research

Principal Investigator, Laboratory of Architecture and Planning, Massachusetts Institute of Technology, Cambridge, MA, 1980-present.
Guest Contractor, Energy and Environment Division, Lawrence Berkeley Laboratory, University of California, Berkeley, 1977-1980.
Associate Specialist, Center for Planning and Development Research, College of Environmental Design, University of California, Berkeley, 1977-1980.

## Professional Experience

Consulting practice in energy conservation and daylighting design, since 1978. Projects include:

Eagleridge Design Competition. Consultant to Goody, Clancy and Associates, Boston, MA.
Midtown Manhattan Development Project: Zoning Regulations Study. Consultant to Davis, Brody and Associates, and Kwartler/Jones Architects, New York City.
U.S. Embassy in San Jose, Costa Rica. Consultant to Marquis Associates, San Francisco, CA.
U.S. Embassy in La Paz, Bolivia. Consultant to Esherick Homsey Dodge and Davis, San Francisco, CA.

Farm Credit Bank in Spokane, WA. Consultant to Walker McGough Foltz Lyerla, Spokane, WA.
State Office Building, Site 1C in Sacramento, CA. Consultant to MBT Associates, San Francisco, CA.

## Awards

1983 Progressive Architecture Design Award (Research Category). Teaching Passive Design in Architecture Project.
1982 Progressive Architecture Design Award (Urban Design Category). Midtown Manhattan Development Project: Zoning Regulations Study.
First Place in the Eagleridge Design Competition.
1980 Owens-Corning Energy Design Award (Commercial Building Category), with Vladimir Bazjanac for work on the Farm Credit Bank in Spokane.
National Endowment for the Arts, Individual Fellowship, 1980-1981.
Third Place Award, The Energy Efficient Office Building Design Competition, sponsored by the California Energy Commission and the Office of the State Architect, 1977.
Fulbright-Hays Fellowship to Italy, 1975-1976.
John K. Branner Travelling Fellowship, 1974-1975.
The A.I.A. Henry Adams Fund Award, 1973.

## Publications

Authored over two dozen papers and articles about energy conservation and daylighting design which have been published. Most recent publication:

> "Daylighting as an Urban Amenity," Proceedings of Streets as Public Property Conference, University of Washington, 1983, pp. 274-279.

## Professional Affiliations

Registered Architect, California Certificate no. C-9604.
Corporate Member, American Institute of Architects.
Member, American Association for the Advancement of Science.
Member, International Solar Energy Society.
Member, Illuminating Engineering Society, Committee Assignment: Daylighting and Office Practices.
U.S. Committee Member, Commission Internationale de l'Eclairage, Committee Assignment: TC 4.2 (Daylighting Committee).
Associate Member, American Society of Heating, Refrigerating and Air-Conditioning Engineers.

# BIOGRAPHICAL SKETCH

Frank Durgin is currently Associate Director of the Wright Brothers Wind Tunnel, Massachusetts Institute of Technology. He received his Bachelor of Science degree in Aeronautics from Massachusetts Institute of Technology in 1948, his Master's degree in 1954 and his Professional degree of Aeronautical Engineer in 1957, again from MIT. Except for the period from 1963 to 1969 when he was involved with several sled track experiments, he has always been directly associated with wind tunnels and especially the necessary instrumentation required for making measurements in such test facilities.

Since joining the Wright Brothers Wind Tunnel in 1969, his main interests have been in the field of aerodynamics of buildings and structures. He has conducted numerous wind tunnel and on-site studies since that time.

## FRANK H. DURGIN - BIOGRAPHICAL DATA

### EDUCATION

| | |
|---|---|
| 1944 | Phillips Exeter Academy |
| 1948 | Massachusetts Institute of Technology, S.B. in Aeronautical Engineerin |
| 1954 | Massachusetts Institute of Technology, S.M. in Aeronautical Engineerin |
| 1957 | Massachusetts Institute of Technology, Aeronautical Engineer |

### POSITIONS HELD

| | |
|---|---|
| 1948-1951 | Research Engineer, Project Meteor, MIT |
| 1951-1961 | Research Engineer, Naval Supersonic Laboratory, MIT |
| 1961-1963 | Senior Research Engineer, Aerophysics Lab., MIT |
| 1963-1969 | Senior Research Engineer, Aeroelastic and Structures Research Lab, MI |
| 1969-1972 | Acting Director, Wright Brothers Memorial Wind Tunnel, MIT |
| 1972-Present | Associate Director, Wright Brothers Memorial Wind Tunnel, MIT |

### PROFESSIONAL SOCIETIES

| | |
|---|---|
| Member | American Institute of Aeronautics and Astronautics |
| Member | National Society of Professional Engineers |

### PATENTS

| | |
|---|---|
| 1965 | Flexure pivot with built-in damping |

### COMMITTEES

| | |
|---|---|
| 1978-1979 | Panel on Full-Scale Measurements of Wind Effects on Buildings and Other Structures, the Wind Engineering Research Council, NSF |
| 1979- | American Society of Civil Engineering, Member of Aerodynamics Committe |
| 1980- | ASCE, Chairman, Task Committee to develop recommended practices for wind tunnel tests of buildings and structures |

### PUBLICATIONS

Covert, E. and Durgin, F.H., "A Note on Aerodynamic Heating," J.Aero.Sc. 23, 699-700 (1965).

Durgin, F.H., "An 'Insulating' Boundary Layer Experiment," J.Aero.Sc. 26, 450-45 (1959).

Kantha, H.L., Lewellen, W.S. and Durgin, F.H., "Response of a Trailing Vortex to Axial Injection into the Core," AIAA J. of Aircraft 9, 254-256 (1972).

## PAPERS

Durgin, F.H. and Floyd, P., "A Study of the Drifting of Snow Under and Around Raised Buildings and Building Complexes," Third International Conference on Wind Effects on Buildings and Structures, Tokyo, 1970.

Durgin, F.H. and Tong, P., "The Effect of Twist Motion on the Dynamic Multimode Response of a Building," Symposium on Flow-Induced Structural Vibrations, sponsored by IUTAM and IAHR at Karlsruhe, Germany, September 1971.

Durgin, F.H., "Use of Anemometers in On-Site Studies of Buildings and Structures and in Particular the Bendix Friez Anemometers," presented at Third National Conference on Wind Eng. Rsch., U. of Florida, February 26-March 1, 1978.

Durgin, F.H., "Some Methods and Techniques Used at the Wright Brothers Wind Tunnel in Ground Wind Studies - With Special Emphasis on a Study of Battery Park City, New York City," presented at Third Nat. Conf. on Wind Eng. Rsch., U. of Florida, 1978.

## MIT REPORTS

Shoulberg, R. H. et al (incl. F.H.Durgin), "An Experimental Investigation of Flat Plate Heat Transfer Coefficients at Mach Numbers of 2, 2.5, and 3 for Surface Temperatures to Stream Total Temperature Ratio of 1.18," MIT NSL WTR 39 (AD 35467), July 1953.

Schindel, L.H. and Durgin, F.H., "Survey of the Downwash Field Behind Rectangular, Trapezoidal, and Delta Wings at Mach Numbers 1.71, 1.99, and 2.50," MIT NSL WTR 29 (AD 31 887), March 1953.

Schindel, L.H. and Durgin, F.H., "Forces on Tails in a Measured Supersonic Downwash Field," MIT NSL WTR 33, October 1953.

Schindel, L.H. and Durgin, F.H., "Wing Tail Interference at Supersonic Speeds," MIT NSL Report 401 (AD 31 385), October 1953.

Schindel, L.H. and Durgin, F.H., "Downwash Field at the Tail Station of a Wing-Body Combination at Mach Numbers 1.51 and 1.99," MIT NSL WTR 37 (AD 31 886), September 1953.

Schindel, L.H. and Durgin, F.H., "Investigation of Temperature Distribution on Conical and Hemispherical Missile Noses, Part I, Equilibrium Temperature," MIT NSL WTR 60, Part I, Eighth Quarter Progress Report, May 1955.

Baron, J.R. and Durgin, F.H., "An Experimental Investigation of Heat Transfer at the Boundaries of Supersonic Nozzles," MIT NSL WTR 65, WADC TR 54-541, December 1954.

Durgin, F.H., "A Wind Tunnel Experiment on the Motion of a Spinning Shell," MIT NSL TR 259, January 1958.

Durgin, F.H., "A Final Report on Phase I of a Program of Experimental and Theoretical Research on the Use of Quasi-Steady Airloads in Aeroelastic Analysis," MIT NSL TR 360, August 1959.

Durgin, F.H. and Polutchko, R.J., "Surface Pressure Tests on Blunt Slab Wings Swept to 0, 45°, 60°, and 70° at Mach Numbers 1.71, 2.6, 4.0, 7.6, and Angles of Attack up to 40°," MIT NSL TR 456, September 1960.

Durgin, F.H. and Langley, J.M.,Jr., "The Naval Supersonic Laboratory 0.002 to 5 pisa 120 Tube Pressure Readout System," MIT AL TR 475-A, October 1960.

Durgin, F.H. and Langley, J.M.,Jr., "The Results of Using the MIT Low Pressure Measuring System," MIT AL TR 475-B, October 1960.

Durgin, F.H., "The Effects of Body Camber on Body Pressure Distributions and Wing Forces for Mach Numbers from 2.0 to 7.6, Part I: Experimental Data," MIT NSF WTR 479, MIT AL TR 4, Part I, ASD TR 61-295, Part I, April 1961.

Beane, B. and Durgin, F.H., "The Effects of Body Camber on Body Pressure Distributions and Wing Forces from M=2 to 7.6, Part II: Comparisons with Theory," MIT AL TR 4, Part II, ASD TR 61-295, Part II, June 1961.

Durgin, F.H. and Tilton, E.L., "The Effect of Camber and Twist on Wing Pressure Distributions for Mach Numbers from 2 to 7.6: Experimental Data," MIT AL TR 4 Part I, ASD TDR 62-557 Part I, December 1962.

Durgin, F.H. and Polutchko, R.J., "A Final Report on Part I Phase II of a Program of Experimental and Theoretical Research on the Use of Quasi-Steady Airloads in Aeroelastic Analysis," MIT NSL TR 423, February 1960.

Brown, J.R., Durgin, F.H. and Noz, W.C., "An Instrument for Measuring Model Pressures in a Low Density Wind Tunnel," MIT AL TR 6, RTD TDR 63-4095, January 1964.

Beane, B.J. and Durgin, F.H., "An Example of Flutter Calculating Using Experimentally Determined Quasi-Steady Aerodynamic Forces," MIT AL TR 9, August 1961.

Durgin, F.H. and Bartlett, C.J., "A Measurement of the Static Aeroelastic Deformation and Loading of a Wing in Supersonic Flow," MIT AL TR 19, ASD TDR 63-366 (AD 422 262), September 1963.

Durgin, F.H., "The Design and Preliminary Testing of a Direct Measuring Skin Friction Meter for Use in the Presence of Heat Transfer," MIT AL TR 93, June 1964.

Durgin, F.H., "A Study of Twist and Camber on Wings in Supersonic Flow," MIT AL TR 95, FDL TDR 64-109 (AD 449 230-L), November 1964.

Durgin, F.H. and Ruetenik, J.R., "An Analysis of the Measured Blast Loads on 60°-Delta Wings at a Mach Number of 1.35," AFFDC TR 66-46, September 1966.

Durgin, F.H., "A Study of the Use of a Sled Track for Re-Entry Vehicle Blast Intercept Simulation," MIT ASRL 148-1, AFWL TR 68-63, 1968.

Durgin, F.H. and Martz, P., "Some Thermodynamic and Other Properties of Freon 114 MIT ASRL 148-2, AFWL TR 68-64, 1968.

Durgin, F.H., "An Investigation of Freon 114 and Sulfur Hexafluoride in a Shock Tube," MIT ASRL 148-3, AFWL TR 68-65, 1969.

Durgin, F.H., "A Method of Investigating Flutter Arming Mechanisms," MIT ASRL 155-1, March 1969.

Durgin, F.H., "An Improved Method for the Design of Wind Tunnel Velocity Profile Grids," Lincoln Lab. Tech. Note 1970-38, December 30, 1970.

Durgin, F.H. and Fanning, W.R., "Wind Pressure Distributions on Randomes in Gradient Flows During and After Construction," Lincoln Lab. Note 1970-37, December 10, 1970.

Durgin, F.H., "A Study of Building Shape and Complex Configuration as They Affect the Drifting of Snow," MIT WBWT 1049, November 1970.

Durgin, F.H., "Wind Tunnel Test of the Gathering Centers and Central Power Statio of the British Petroleum Co.," performed for Brown and Root Co., Inc., MIT WBWT TR 1051, November 1970.

Durgin, F.H., "Wind Tunnel Test of Westgate II (Tang Hall) MIT Campus First Series," MIT WBWT TR 1050, April 1971.

Durgin, F.H., "Wind Tunnel Test of Rochester Institute of Technology Walkway," MIT WBWT TR 1053, August 1970.

Hansen, R.J., Durgin, F.H., Reed, J., Anagnostopoulos, S. and Burr, C., "Wind-Induced Motion Effects on the New England Merchants National Bank Building," Depts. of Aero/Astro and Civil Eng., MIT, September 1971.

Durgin, F.H., O'Neill, T. and Debout, B., "Roof Lift Tests of the TROCAL Roof System," for Dynamite Nobel of Am., MIT WBWT TR 1062, 1972.

Durgin, F.H., "Calibration of the Maximum Anemometer," for Maximum Inc., MIT WBWT TR 1063, October 1971.

Durgin, F.H., "Wind Tunnel Test of Westgate II (Tang Hall) MIT Campus Second Series," MIT WBWT TR 1067, February 1972.

Tong, P. and Durgin, F.H., "Aeroelastic Wind Tunnel Tests of a Rectangular Prism," MIT WBWT TR 1068, April 1972.

Durgin, F.H., "First Test of AVCO Large Probe Decent Configuration," MIT WBWT TR 1071, June 1972.

Durgin, F.H., "Calibration of Two Anemometers," for Woods Hole Oceanographic Institute, MIT WBWT TR 1072, July 1972.

Durgin, F.H., "A Wind Tunnel Force and Pressure Test of a 2-1 Ellipsoid Radome," General Electric Co., Heavy Military Electronics Dept., MIT WBWT TR 1076, Nov. 1973.

Durgin, F. H. et al, "Wind Tunnel Pressure Test of a 1-600 Scale Model of the John Hancock Building," MIT WBWT TR 1079, August 1974 [to be published at termination of suit]

Durgin, F. H. et al, "On-Site Studies at the John Hancock Building," [to be published at termination of suit]

Durgin, F.H., "Test of Effectiveness of Several Snow Fences," for Westchester Chemical Co., MIT WBWT TR 1089, July 1974.

Durgin, F.H., Harmon, T. and Epstein, R., "Aeroelastic Wind Tunnel Test of 1/600 Scale Model of John Hancock Building in Boston," for John Hancock Mutual Life Insurance Co., MIT WBWT TR 1090, August 1974 to December 1974 [to be published at termination of suit].

Durgin, F.H., Epstein, R. and Acree, A.C.,Jr., "A Ground Wind Study of the Explosives Handling Wharf #1," for AWA-ABAM a Joint Venture, MIT WBWT TR 1091, February 1975.

Luh, P. and Durgin, F.H., "A Wind Tunnel Study of Wind Pressure on the College Life Insurance Company Headquarters," for College Park Corp., MIT WBWT TR 1096, August 1976.

Durgin, F.H. and Radovsky, S., "A Ground Wind Velocity Study of Battery Park City, New York, N.Y., MIT WBWT TR 1097, May 1976.

Durgin, F.H., Hansen, R.J., Harmon, T. and Strawbridge, J., "Some Examples of Pressure Coefficients Measured on a Tall Building," MIT Dept. of Civil Eng., Report R76-11, February 1976.

Fanucci, J.P. and Durgin, F.H., "Static and Dynamic Calibration of a Corona Discharge Anemometer," for Air Force Geophysics Laboratory, MIT WBWT TR 1101, December 1976.

Durgin, F.H., "A Wind Tunnel Study of the Pressures on the College Life Insurance Company Headquarters--Second Phase," for College Park Corp., MIT WBWT TR 1102, October 1977.

Fanucci, J.P. and Durgin, F.H., "Some Characteristics of Stagnating Turbulent Flows Near Two- and Three-Dimensional Bodies," for Naval Underwater Systems Center, MIT WBWT TR 1104, December 1977.

# STAFF RESUMES

# LINDA SUSAN BOURQUE

4 Henchman Street
Home: 617/523-4022 Boston, Massachusets 02113 Work: 617/722-4300

## PROFESSIONAL EXPERIENCE

BOSTON REDEVELOPMENT AUTHORITY
Boston, Massachusetts
Environmental Planning Specialist, 1973 to Present

Environmental planning in air quality, noise, water quality, groundwater, and urban wind problems.

Develop environmental policies for Boston's Downtown Development Guidelines for 1980 to 1990. Coordinate policies with commercial, manufacturing, residential, and industrial growth components of Guidelines.

Integrate environmental and energy policies into financial feasibility analyses and development guidelines for individual development proposals. Negotiate with developers to tailor major project proposals to reflect environmental and energy concerns.

Serve on U.S. Environmental Protection Agency's Citizen's Advisory Committee overseeing development of options for treating and disposing of wastewater from Metropolitan Boston.

Write environmental impact reports for projects undertaken by the Boston Redevelopment Authority.

Evaluate Federal and State environmental regulations and programs affecting the City of Boston. Work with regulatory agencies to address Boston's environmental concerns.

Specific tasks have included:

- o Initiation of engineering groundwater/building foundation study for City of Boston's filled land area.
- o Provision of technical assistance to Boston Economic Development and Industrial Corporation and Boston Air Pollution Control Commission on two-year U.S. Department of Housing and Urban Development air quality demonstration grant. Development of economic incentives for industrial growth through application of options under the Clean Air Act.
- o Production of slide show for the U.S. Environmental Protection Agency to demonstrate Clean Air Act options to industries and utilities throughout the country.

EUDCATION

BOSTON UNIVERSITY
Boston, Massachusetts
Completed all work but thesis toward Master of Arts in Physical Geography

- Concentration in Climatology.
- Received Teaching Assistant Scholarship and assisted faculty member in instruction of Physical Geography courses.

HARVARD UNIVERSITY
Cambridge, Massachusetts
Environmental Management and Environmental Health courses

BOSTON ARCHITECTURAL CENTER
Boston, Massachusetts
Conservation of Energy Lecture Series

BOSTON UNIVERSITY
Boston, Massachusetts
Bachelor of Arts, May, 1971
Physical Geography concentration; Geology minor.

COMMUNITY AFFILIATIONS

Boston Harbor Citizens Advisory Committee
Physicians for Social Responsibility
New England Sierra Club

REFERENCES

Available upon request.

**Barbara L. Barros**
Urban Designer-City Planner

14 Bradley Woods Drive • Hingham, Mass. 02043 • (617) 740-1055

Urban Designer, Boston Redevelopment Authority, since May 1983.

Responsible for design guidelines for new development in Central Boston as part of the Boston Tomorrow project which is formulating development policy for the city. This project commenced with the publication "Boston Tomorrow: Issues of Development", for which Ms. Barros wrote the Urban Design chapter.

This publication has been followed by the preparation of draft development policy statements which will be used in a public discussion project. The goal of this process is to establish a set of development policies and design guidelines for Central Boston.

## EXPERIENCE

**Urban Designer,** Stull Associates, Boston, Mass. 1/82-Present.
Projects: Bird Island Flats Project, Massport, Logan Airport, Boston.
Century Freeway Corridor, Cal., Economic Dev. Strategy.

**Urban Designer/City Planner,** City of Pittsfield Planning Board,
Pittsfield, Mass. 1/75-7/79.
Projects: Downtown Revitalization Planning; Zoning;
Project Supervisor—Historical Survey and Planning.

**Planner,** Franklin County Regional Planning Commission,
Greenfield, Mass., 73-74.

**Site Planner,** Gordon Ainsworth and Associates,
South Deerfield, Mass., 72-73.

## EDUCATION

**Harvard University Graduate School of Design,** Cambridge, Mass.
Master of Landscape Architecture in Urban Design, 9/79-6/81.

**University of Massachusetts,** Amherst, Mass.
Bachelor of Science in Urban Design/City Planning, 71-72, 75.

**Conway School of Landscape Design,** Conway, Mass., 9/72-6/73.

**Rhode Island School of Design,** Providence, R.I., 9/68-6/69.

## AREAS OF SPECIAL EXPERTISE

- Urban Revitalization Planning—all aspects.
- Project Initiation and Administration.
- Community Participation and Public Awareness.

**SANDRA SWAILE, Architectural Designer/Draftsman**
**48 Pratt Street Allston, Mass.02134 254-3178**

**ACKGROUND**

A dedicated, facile, and flexible designer with a broad range of skills from planning& schematics thru production & construction

**XPERIENCE**

| | |
|---|---|
| N.Y.C.<br>'55-'60 | Commercial art, technical illustration |
| Pgh,Pa.<br>'64-'66 | Redevelopment Authority of Allegheny County<br>Pittsburgh Regional Planning Association<br><br>Cartography, utility maps, site plans<br>Mechanicals, type spec, charts, logos |
| Boston<br>'67-'84 | Boston Redevelopment Authority<br><br>Programs, proposals, design<br>Delineation, details, models<br>Cost estimates, specifications<br>Regulatory & development issues |

**IOJECTS**

Conceived urban design & master plans,
Analyzed massing & circulation

Generated schematic proposals for residential infill & districts, commercial malls & centers, university & hospital expansions, cable facilities,& transport nodes

Designed open space & streetscapes, public plazas & parking lots. Built parks & playgrounds

Developed designs of community centers, housing projects, institutional & commercial buildings,mixed use structures

Produced working drawings for parks, commercial rehabs, utility centers,& exhibition structures

Originated & conducted DOE research project on ice for thermal storage & renewable energy

Supervised construction of Boston-200 exhibits & booths

**JCATION**

Carnegie Mellon University; Bach.F.Arts
Boston Architectural Center; Bach. Arch.
Boston University; Master Urban Affairs

# RESUME

Victor W. Karen

Registered Architect, Commonwealth of Massachusetts

## EDUCATION:

Massachusetts Institute of Technology
Bachelor of Science, 1974
Master of Architecture, 1979

## EXPERIENCE:

Boston Redevelopment Authority. May 1983 - present

Responsibilities include design review of proposals for major downtown office and retail buildings and the development of urban design guidelines for publically owned parcels. Aspects which are particularly emphasized are ameloiration of adverse impacts of new development on public spaces (i.e. wind, shadow) and the enhancement of use patterns, streetscape, district, and city character.

Hardaway Associates, Newton, Ma. April - May 1983

Project Architect for hotel ballroom expansion and renovation.

Moore-Heder, Architects, Cambridge, Ma. June 1978 - November 1982

Project Architect for renovations to a historic City Hall; rehabilitation of 6 row houses into 23 apartments; addition to a college residence fraternity; public space improvements for a neighborhood commercial area; and various other projects.

Urban Design Staff for the Lowell (Massachusetts), Preservation Plan; Aesthetics in Transportation and Auto-Restricted Zone Project, both published by the U.S. Department of Transportation.

Victor Karen, Architectural Designer. 1980 - present

Architect for four single family residences including new construction, rehabilitation, and additions to existing houses.

## PROFESSIONAL AFFILIATIONS:

Member Boston Society of Architects
American Institute of Architects

**GREGORY WILSON PERKINS**
387 Beacon Street, Apt. 4
Boston, MA 02116
(617) 536-8632

Born: November 6, 1952, Danbury, CT
Marital Status: Single
Height: 6' 2"
Weight: 170 lbs.

## EDUCATION

University of North Carolina at Chapel Hill - September 1975 to August 1978.
Master of Regional Planning - Department of City and Regional Planning, December, 1978.
Concentration: Economic development.
Scholarship: Tuition grant 1976 - 1977, 3.4 accumulative average.

Syracuse University, Syracuse, New York - September 1970 to May 1974.
Bachelor of Arts Degree - American Studies, May 1974.
Concentration: Interdisciplinary urban affairs; economics, geography, political science, American literature, history, and philosophy.
Scholarship: 3.3 accumulative average, Honors Program, Regents' Scholarship and Incentive Award (1970 to 1974), Joseph P. Nelson Award, 1973.

## WORK EXPERIENCE

July 1979 to Present: Economic Analyst, Research Department, Boston Redevelopment Authority, Boston, Massachusetts.

Supervisor: Mr. Alexander Ganz
Duties: Responsible for monitoring economic characteristics of Boston for the Planning and Redevelopment Authority concerning: employment, unemployment, labor force, earned income, personal income, export role, and cost-of-living data. Preparation of research reports covering descriptive economic analysis and projections of future trends of the Boston economy. Monitoring and analyzing office and retail market characteristics and needs for the City. Tracking investment, employment, and project characteristics of redevelopment projects of the Authority. Providing research assistance for specific projects of the Authority, including Air Quality offsets pilot study, Comprehensive Economic Development Strategy (CEDS) report, Enterprise Zones, and UDAG grant applications. Preparing economic background information and market impact assessment of development activity for Downtown Development Policy Planning Project. Studying City of Boston fiscal trends in expenditures and revenues (taxation). Future work to include joint efforts in the preparation of an analytic computer file on city development projects, an econometric model of the Boston economy, determination of public infrastructure and capital investment needs, and neighborhood employment projections.

May 1975 to mid-August 1975: Planning Intern, Central New York Regional Planning and Development Board, Syracuse, New York.

Supervisor: Mr. Robert Anderson
Duties: Initial research effort on Air Quality Maintenance Analysis Plan for central New York planning region. Responsible for gathering population, employment, transportation, and energy emissions information through field study and resource research. Used population projections, trend analysis, and stepdown procedures for tracking emission levels and pinpointing critical areas for horizon years 1980 and 1990. Also, assisted in A-95 Clearinghouse process and housing code enforcement update. Worked closely with associates in determining proper procedures and techniques.

## VOLUNTARY WORK EXPERIENCE

Spring 1977: Participated in community needs analysis survey and agency study of employment conditions and services in Durham, North Carolina. Worked in concert with Durham-Orange Employment and Training Consortium and Durham Technical Institute. Subsequently, partipated in presentation of paper, "Report on a Study of Client Resources and Employment Linkages in Durham, North Carolina," at Southeastern Regional Association of Manpower Planners, March 24, 1977 at Asheville, N.C. Professor Ed Bergman, Supervisor.

Spring 1977: Prepared background report with Workshop on Socio-Economic Development in the South (Chapel Hill, N.C.) on "Indicators of Economic Growth, Industrial Development, and Economic Development in the South," presented to Mr. Lamond Godwin, National Rural Center, Atlanta, Georgia. Professor Emil Malizia, Supervisor.

Spring 1976: Participated as data research gatherer for further work on shift-share wage analysis of North Carolina industries for Dr. Emil Malizia of the Department of City and Regional Planning who has previously produced The Earnings of North Carolinians for the Office of State Planning.

Spring 1973: Planning Intern, New York State Department of Transportation, Syracuse Regional Office. Reviewed environmental, social, and economic selection criteria of transportation corridor paths for highway construction. Researched transportation planning decisions for Radisson New Community (N.Y.). Mr. John Shub, Supervisor.

## SKILLS/AREAS OF SPECIALIZATION

### MANPOWER AND ECONOMIC DEVELOPMENT:

- Trained in economic development, manpower/labor-market economics, inner-city economic development, labor law, and practice-related research. Analytical techniques include: benefit-cost, economic base, input-output, population projection, shift-share, and social indicator construction.
- Working knowledge of programs of and funding under Comprehensive Employment and Training Act and Economic Development Administration. Familiar with the National Labor Relations Act.

### HOUSING, COMMUNITY DEVELOPMENT and SOCIAL POLICY:

- Trained in housing policy, real estate investment, neighborhood development planning, and human services policy planning design and evaluation. Emphasis on program plannning, project design, and evaluation methods; investment analysis; needs determination for target areas; and program agency resource linkages.
- Knowledge of Federal programs; housing rehabilitation, homesteading, Section 8, housing assistance, and community development housing tools. Understanding of Community Development Block Grants, and commercial revitalization strategies. Familiar with Human Services and income maintenance programs.

### FISCAL POLICY and MANAGEMENT:

- Trained in fiscal policy, taxation, intergovernmental relations, and administration and management of public agencies.
- Knowledge of procedures of financial and taxation reporting, budgeting, management information systems, management by objectives, contracting, and project administration.

## SKILLS/AREAS OF SPECIALIZATION (continued)

STATISTICAL, RESEARCH and WRITING:

- Working knowledge and training in descriptive and inferential statistics, probability, econometrics, regression, public investment analysis, projection methods, techniques of employment and income analysis, and real estate finance.
- Experience with SPSS, FORTRAN, and BASIC computer languages applied to statistical research in social and economic policy.
- Experience in library/document research and statistical data gathering. Participated in design, implementation, and analysis of field surveys and agency interviews.
- Writing skills for technical memoranda, descriptive/expository reports, and research studies in various economic and planning fields.

## PAPERS AND REPORTS

### Academic

THE ROLE OF THE DEVELOPMENT CORPORATION IN MANPOWER AND ECONOMIC DEVELOPMENT FOR TARGETED NEIGHBORHOODS. Summer 1978. (Unpublished departmental paper)

SOUTHERN UNDERDEVELOPMENT AND THE RURAL SOUTH: EDUCATION. Spring 1977. (Prepared for the National Rural Center; Mr. Lamond Godwin, Southern Regional Director.)

URBAN ECONOMIC DEVELOPMENT IN PHILADELPHIA. Spring 1977. (Unpublished paper)

LOW-INCOME COOPERATIVE HOUSING. Summer 1977. (Unpublished paper)

A PROPOSED CONCENTRATED HOUSING REHABILITATION STRATEGY FOR WEST CENTER CITY, WILMINGTON, DELAWARE. With others. November 1976. (Submitted to Commissioner of Licenses and Inspections, Mr. Robert C. Hubbard, City of Wilmington).

INNER CITY REVITALIZATION: THEORETICAL APPROACHES AND CORRESPONDING NEIGHBORHOOD STRATEGIES. Spring 1976. (Unpublished paper)

ECONOMIC DEVELOPMENT EXPERIENCES IN SOUTHWESTERN FRANCE. Fall 1975. (Unpublished)

AMERICAN HOUSING POLICY FROM 1930 TO 1974: AN EXPERIMENT IN GOVERNMENT. Spring 1974. (American Studies Senior Thesis)

### Work-Related

BOSTON'S OFFICE INDUSTRY: A LONG-TERM PERSPECTIVE, 1980-1990. Summer 1982. (Forthcoming)

TWENTY TWO YEARS OF BOSTON'S FISCAL RECORD: A REVIEW OF REVENUE AND EXPENDITURE TRENDS FOR BOSTON CITY GOVERNMENT, 1960-1982. Summer 1982. (Forthcoming)

THE RECESSION'S EFFECT ON METROPOLITAN BOSTON, 1980-1981. June 1982.

BOSTON EMPLOYMENT TRENDS, 1979-1980-1981. June 1982.

THE BOSTON ECONOMY: MID-YEAR 1982. With Alexander Ganz. June 1982.

CITY OF BOSTON POPULATION PROJECTIONS: A SUMMARY. With Alexander Ganz. February 1982.

POPULATION AND EMPLOYMENT PROJECTIONS FOR BOSTON AND THE MAPC REGION 1990, 2000, 2010 (Prepared for Consideration of the MAPC Executive Committee). December 1981. With Alex Ganz and Margaret O'Brien.

VISITORS AND TOURISTS TO BOSTON, 1978-1980. October 1981.

CHARACTERISTICS OF THE GROWTH OF SERVICES EMPLOYMENT IN BOSTON AND THE SUBURBAN RING, 1963-1979. With Otis Ginoza, Principal Author. September 1981. (Unpublished)

THE ROLE OF CITY GOVERNMENT IN BOSTON AND THE NATION'S THIRTY LARGEST CITIES: A COMPARATIVE VIEW. With Alexander Ganz. July 1981.

RETAIL TRADE IN BOSTON: YESTERDAY, TODAY, AND TOMORROW. With Frances Larson. June 1981. (Unpublished)

EVALUATION OF THE IMPACT OF NEW PUBLIC OFFICE CONSTRUCTION ON THE OFFICE MARKET IN CENTRAL BOSTON. June 1981.

IMPACT OF THE BOSTON CAPITAL CONSTRUCTION FREEZE ON JOBS AND TAX REVENUE. With Alexander Ganz and Frances Larson. April 1981.

PERFORMANCE OF BOSTON CITY GOVERNMENT, 1967-81. With Alexander Ganz. April 1981.

ECONOMIC CHARACTERISTICS. May 1981. Excerpt from Boston Bond Flyer.

# PAUL E. REAVIS, JR., AIA

| | |
|---|---|
| Current Position: | Chief Senior Architect<br>Boston Redevelopment Authority |
| Registration: | Architect: South Carolina, North Carolina, Virginia and Massachusetts<br>Real Estate Broker: North Carolina |
| Certification: | National Council of Architectural Registration Boards |
| Professional Affiliations: | American Institute of Architects, Member<br>Charleston Council of Architects, President 1981-1982<br>AIA Historic Resources Committee, Open Member<br>AIA Planning and Urban Design Committee, Open Member<br>Institute for Urban Design, Charter Member<br>Association for Preservation Technology, Member<br>National Trust for Historic Preservation, Member<br>Construction Specification Institute, Past Member<br>American Planning Association, Charter Member |
| Education: | Master of Architect, 1973<br>College of Architecture, Clemson University<br><br>Bachelor of Arts, Pre-Architecture, 1971<br>College of Architecture, Clemson University |
| Study/Tour: | National League of Cities, Urban Environmental Design Project, 1980. A study of the strategies, ordinances, and projects used in Seattle and Baltimore to create a climate for urban investment. |

Professional Experience:

| | |
|---|---|
| August, 1983 - Present | Chief Senior Architect<br>Boston Redevelopment Authority<br>Boston, Massachusetts |
| April, 1983 - July, 1983 | Acting Director<br>Department of Planning and Urban Development<br>City of Charleston, South Carolina |
| June, 1977 - March, 1983 | Zoning Administrator<br>Department of Planning and Urban Development<br>City of Charleston, South Carolina |

## Professional Experience: (Continued)

| | |
|---|---|
| June, 1975 -<br>June, 1977 | City Planner<br>Community Development Department<br>City of Charlotte, North Carolina |
| August, 1973 -<br>May, 1977 | Project Manager<br>J. N. Pease Associates<br>Charlotte, North Carolina |

## Teaching Experience:

| | |
|---|---|
| January, 1973 -<br>May, 1973 | Graduate Instructor: First Year Design<br>College of Architecture, Clemson University |
| August, 1972 -<br>January, 1973 | Graduate Teaching Assistant: Second Year Design<br>College of Architecture, Clemson University |

# ROBERT KROIN, Architect and Urban Designer

Current Position: Chief Senior Architect
Boston Redevelopment Authority

Registration: Massachusetts #3734, 1973

## EDUCATION

| | |
|---|---|
| 1964-68 | Harvard University<br>Graduate School of Design<br>M.Arch. 1968 |
| 1963-65 | Harvard University<br>Graduate School of Arts and Sciences<br>M.A. 1966 |
| 1959-63 | Brown University<br>A.B. 1963 - Magna cum Laude |

## HONORS AND AWARDS

| | |
|---|---|
| 1965-68 | Harvard GSD Fellowship |
| 1963-64 | Woodrow Wilson Fellowship |
| 1963 | Highest Honors in English |
| 1963 | Phi Beta Kappa |

## PROFESSIONAL EXPERIENCE

| | |
|---|---|
| October, 1969 - Present | Boston Redevelopment Authority<br>One City Hall Square, Boston, MA<br>Chief Senior Architect, Department of Urban Design<br>Chief Project Architect: North Station Area, Copley Place, Harvard Medical Area, Auditorium Expansion, and major downtown projects |
| June, 1968 - October, 1969 | Edgar Wood and Associates, Architects<br>14 Alleyne Street, Quincy, MA<br>Project Designer: Weymouthport Apartments and Marina, Otis Elevator Building, Furnacebrook Medical Office Building |

## PROFESSIONAL EXPERIENCE (Continued)

| | |
|---|---|
| October, 1967 -<br>February, 1968 | Kenneth Kruger, Architect/Engineer, AIA<br>2 Central Square, Cambridge, MA |
| | Designer: Trenton Junior High School |
| 1972 - Present | Guest Critic and Lecturer:<br>Harvard, M.I.T., Boston Architectural Center |

## TRAVEL

Major cities and regions of France, Britain, Holland, Belgium, Switzerland, Italy, Finland, Scandinavia, and United States in 1962, 1966, 1972, and 1973.

**Assurance of Compliance with National Endowment for the Arts Regulations** under Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, and Title IX of the Education Amendments of 1972.

Boston Redevelopment Authority (hereafter called the "Applicant") **Hereby Agrees** that it will comply with Title VI of the Civil Rights Act of 1964 (42 U.S.C. 2000d et seq.), Section 504 of the Rehabilitation Act of 1973 (29 U.S.C. 794) and, where applicable, Title IX of the Education Amendments of 1972 (20 U.S.C. 1681 et seq.) and all regulations of the National Endowment for the Arts issued pursuant to these statutes. Title VI, Section 504, and Title IX prohibit discrimination on the basis of race, color, national origin, handicap, or sex in any program or activity receiving Endowment support. The Applicant **Hereby Gives Assurance** that it immediately will take any measures necessary to comply.

This assurance shall obligate the Applicant for the period during which the federal financial assistance is extended. There are two exceptions. If any personal property is acquired with Endowment assistance, this assurance shall obligate the Applicant for the period during which it retains ownership or possession of that property. If any real property or structure is improved with Endowment support, this assurance shall obligate the Applicant or any transferee for as long as the property or structure is used for the grant or similar purposes.

This assurance is given in connection with any and all financial assistance from the Endowment after the date this form is signed. This includes payments after such date for financial assistance approved before such date. The Applicant recognizes and agrees that any such assistance will be extended in reliance on the representations and agreements made in this assurance, and that the United States shall have the right to seek judicial enforcement of this assurance. This assurance is binding on the Applicant, its successors, transferees, and assignees, and on the authorized official whose signature appears below.

Boston Redevelopment Authority
Applicant

Boston Redevelopment Authority
Applicant's mailing address
One City Hall Square

Boston, MA 02201

By (President, Chairman of the Board, or comparable authorized official)

December 2[illegible], 1983
Dated

**Boston**
**Redevelopment**
**Authority**

December 20, 1983

National Endowment for the Arts
Grants Office / D.A.P.
2401 E. Street, N.W.
Washington, DC  20506

Dear Sir/Madam:

The Boston Redevelopment Authority is a Commonwealth of Massachusetts State-Chartered Authority. The Authority is classified as a Local Government Entity and as such is exempt from revenue taxation under IRS by-laws.

Sincerely,

Joseph J Noonan

Joseph J. Noonan
Controller

MS1/NN/122083

1 City Hall Square
Boston, Massachusetts 02201
(617) 722-4300

Boston Redevelopment Authority is an Equal Opportunity / Affirmative Action Employer

FORM ST-2

# THE COMMONWEALTH OF MASSACHUSETTS

Department of Corporations and Taxation

Sales and Use Tax Bureau

## CERTIFICATE OF EXEMPTION

Certification is hereby made that the organization herein named is an exempt purchaser under Chapter 14, Acts of 1966, Section 1, Subsections 5 (d) or 5 (e). All purchases of tangible personal property by this organization are exempt from taxation under said Act to the extent that such property is used in the conduct of the business of the purchaser.

BOSTON REDEVELOPMENT
AUTHORITY
73 TREMONT ST
BOSTON

E 046 006 386 EXEMPTION NUMBER

MARCH 31 1966 ISSUE DATE

Guy J. Rizzetto
Commissioner of Corporations
and Taxation

NOT ASSIGNABLE OR TRANSFERABLE.

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THE COMMONWEALTH OF MASSACHUSETTS — DEPARTMENT OF CORPORATIONS AND TAXATION

SALES AND USE TAX BUREAU

IMPORTANT NOTICE

Chapter 757 of the Acts of 1967, effective January 1, 1968, changes the basis of exempti from the sales and use tax for certain organizations. Commencing January 1, 1968, only organizations, corporations, foundations and institutions which are exempt under Section 501 (c) (3) of the U. S. Internal Revenue Code as amended will be entitled to exemption under the sales and use tax law on purchases.

Therefore, if you wish to continue your Massachusetts sales tax exemption status, you must submit immediately a copy of your letter of exemption from the U. S. Internal Revenue Service to the Sales and Use Tax Bureau, Exemption Section, P. O. Box 2061, Boston 02106. Only a Section 501 (c) (3) exemption letter will entitle you to keep your sales and use tax exemption. All others will be revoked.

Failure to furnish this information will mean that your exemption will be revoked. Plea give this matter your immediate attention.

This notice is sent to all holders of exemption certificates. If you are an agency of the United States or an agency or political subdivision of the Commonwealth, please disrega this notice.

Cleo F. Jaillet
Commissioner of Corporations and Taxation

# *DESIGN PERFORMANCE STANDARDS*

## WIND & AIR CIRCULATION
## SUNLIGHT & DAYLIGHT

SUPPLEMENTARY MATERIAL

**BOSTON REDEVELOPMENT AUTHORITY GRANT APPLICATION**

**Submitted to the**
**NATIONAL ENDOWMENT FOR THE ARTS**
**DESIGN EXPLORATION/RESEARCH: POLICY & DESIGN**

**December 1983**

Boston Redevelopment Authority
Robert J. Ryan, Director

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3. "The Utilization of Daylight as an Urban Design Strategy" by Harvey Bryan, et al
4. "Pedestrian Level Winds: A Brief Review", Frank Durgin and Alfred Choch
5. "Daylight in Manhattan" references to work by Harvey Bryan
6. Urban Design and Planning Citation, Harvey Bryan, Consultant

IV. Work Plan (to be forwarded)

# Introduction

The Boston Redevelopment Authority is the planning and development agency for the City of Boston. The development atmosphere in the City has been very strong for the past several years and all indications are that there will continue to be a strong market in the next decade. The current office vacancy rate in Boston is only 1.6%. There is also a growing interest in promoting development outside of the financial core and into other currently underutilized downtown areas. This continued growth stresses the need for specific design performance guidelines that will enhance rather than exacerbate microclimatic conditions and allow pedestrians to benefit from natural environmental variables. We want to ensure that no new high velocity wind site will be created by new construction to make the city dangerous and inhospitable to the thousands of people visiting, living, and working here every day. We want to preserve air flow channels that disperse air pollutants and ensure that they are not hindered by construction that traps air into street canyons, forms eddies or blocks beneficial sea breezes. There also is a strong need to preserve light at the pedestrian level. This is important not only because of the comfort provided by sunlight and daylight, but several studies suggest that there is a psychological and physiological need for exposure to light that can go unmet when in very dense urban areas.

Today, there are no specific design performance standards and implementation methodologies available to urban designers and planners. For example, there is technology for predicting wind velocities around new structures, however, a methodology needs to be developed that can adapt the technology to accurately predict the influence of the structure beyond the immediate project site where the actual impact may be more adverse and counterintuitive.

It is our intention to develop standards and methodologies to advance the state-of-the-art in addressing the interaction of building design and microclimate. The City of Boston will be used to test these methodologies, however, we would like to emphasize that these methodologies should be adaptable to other cities as a comprehensive approach to incorporating microclimatic concerns into design. Boston is a city of complex street patterns and varying architectural styles from low profile brownstones to modern high-rise structures. We, therefore, feel that it is a very appropriate location in which to test these policies and methodologies.

Since 1982, the BRA has been undertaking a special effort to formulate development policy and design guidelines for Central Boston. Under the title "Boston Tomorrow", the project commenced with publications on the issues of development and is now in the phase of preparing policy statements and identifying a public process and special studies which will lead to design guidelines.

One of the most important areas of concern in the Boston Tomorrow project is how new development can be guided in order to prevent adverse winds and air stagnation and to preserve sunshine and daylight in public areas. This design performance standards study, requiring particular technical expertise and research, could not be accomplished without the financial support of the NEA.

MS1/O/122083

# THE GRANITE GARDEN

## Urban Nature and Human Design

ANNE WHISTON SPIRN

*Basic Books, Inc., Publishers*

NEW YORK

# Dirt and Discomfort

ON A CLEAR DAY the bright blue sky overhead shades to leaden gray around the city; in summer the skyline shimmers with heat. The image is commonplace, no copy for headline news, yet the everyday impact on health is pervasive and deadly. The very old, the very young, and those with heart and lung disease suffer city dirt and heat most intensely, but over the years dirt and discomfort take their toll on healthy people, too. The impact of air pollution on children is the most insidious and long-lasting.

The air in New York City and Los Angeles, cities that contain almost 8 percent of the nation's population, fails to meet U.S. ambient air quality standards most of the time; three days out of four in New York and seven days out of ten in Los Angeles.[1] When the air is "very unhealthy" (one in four days in New York and one in three days in Los Angeles),[2] many people may cough, feel drowsy, or suffer a mild headache, but officials warn the elderly and those with heart and lung disease to remain indoors and limit physical exertion.

Even when overall air quality is deemed "adequate," carbon monoxide and poisonous dust on sidewalks and playgrounds may reach dangerous levels. Increased lead poisoning among inner-city and suburban children is now linked more to the lead in urban dust than to paint, and loss of physical coordination from carbon monoxide inhalation has been cited as a cause of accidents in heavy traffic.

In summer, the further insult of heat is added to dirt. The city, especially its dense core, is both hotter and less ventilated by winds than the outlying countryside. The city's added heat load increases summer discomfort and the energy required for air conditioning day to

Problems of dirt and comfort are linked. Automobiles, power plants, furnaces, and factories poison and heat the air. Dense buildings block the wind, preventing the dispersion of dirt and heat. Valleys and street canyons trap pollutants. Stone and concrete absorb heat and store it during the day, then give it off at night. Together, these factors produce a city climate distinct from that of the surrounding countryside. Urban activities, forms, and materials, and the manner in which they are combined, account for the wide variation in microclimate and degree of air pollution from spot to spot within the city. The characteristics of city climate (see table 2.1), its causes and effects, are well known, but that knowledge is rarely exploited.

TABLE 2.1
*Characteristics of Urban Climate*

| *Element* | *Compared to Rural Environs* |
|---|---|
| Contaminants: | |
| Condensation nuclei | 10 times more |
| Particulates | 10 times more |
| Gaseous admixtures | 5–25 times more |
| Radiation: | |
| Total on horizontal surface | 0–20% less |
| Ultraviolet, winter | 30% less |
| Ultraviolet, summer | 5% less |
| Sunshine duration | 5–15% less |
| Cloudiness: | |
| Clouds | 5–10% more |
| Fog, winter | 100% more |
| Fog, summer | 30% more |
| Precipitation: | |
| Amounts | 5–15% more |
| Days with less than 5mm | 10% more |
| Snowfall, inner city | 5–10% less |
| Snowfall, lee of city | 10% more |
| Thunderstorms | 10–15% more |
| Temperature: | |
| Annual mean | 0.5–3°C more |
| Winter minima (average) | 1–2°C more |
| Summer maxima | 1–3°C more |
| Heating degree days | 10% less |
| Relative humidity: | |
| Annual mean | 6% less |
| Winter | 2% less |
| Summer | 8% less |
| Wind speed: | |
| Annual mean | 20–30% less |
| Extreme gusts | 10–20% less |
| Calm | 5–20% more |

ners—are oblivious to the effects they have on urban climate and air quality. Air pollution, discomfort, and energy consumption are treated separately when they are addressed at all, not as the interrelated whole they represent. Attempts to solve one problem often create several new ones.

## *Poisons in the Air*

Pollution, illness, and cities have an ancient association. In A.D. 61 Seneca complained of Rome, "As soon as I escaped from the oppressive atmosphere of the city, and from that awful odor of reeking kitchens which, when in use, pour forth a ruinous mess of steam and soot, I perceived at once that my health was mended."[3] London was known for foul air as early as A.D. 852.[4] The first smoke abatement law, enacted in London in 1273, prohibited the use of coal as "prejudicial to health,"[5] but it was short-lived, undermined by the lack of a cheap alternative to bituminous coal. London's air pollution problem grew with the city, and by the sixteenth century the air of London was notorious. In 1661, John Evelyn complained, "Whilst these [chimneys] are belching it forth their sooty jaws, the City of *London* resembles the face rather of *Mount Aetna*, the *Court of Vulcan*, *Stromboli*, or the *Suburbs of Hell*, than an Assembly of Rational Creatures, and the Imperial seat of our incomparable *Monarch* . . . the weary *Traveller*, at many Miles distance, sooner smells, than sees the City to which he repairs."[6]

A London physician, Harold Des Veaux, coined the term "smog" (smoke plus fog) in 1905 to describe a phenomenon that by then had been known for centuries.[7] Londoners had long associated smog with illness, but in the nineteenth century, when officials began to tally "excess deaths" during particularly severe episodes, 650 excess deaths were documented during a two-day episode in December 1873 and 1,176 during a three-day period in January 1880. This trend continued into the twentieth century, culminating in the infamous incident of December 5-9, 1952, when "killer smog" caused the deaths of more than 4,000 people.[8]

Five air pollutants—sulfur dioxide, nitrogen oxides, ozone, carbon monoxide, and total suspended particulates—are monitored in most tion. The primary sources and effects of these pollutants are indicated in table 2.2. Sulfur dioxide ($SO_2$), a primary ingredient of London smog, finds most of its victims among patients with chronic respiratory and heart diseases. Long-term exposure to even low levels of atmospheric sulfur dioxide has been implicated as a cause of emphysema and chronic bronchitis. John Evelyn's words in 1661 remain a classic description of sulfur dioxide pollution: "this is that pernicious Smoake which sullyes all her Glory, superinducing a sooty Crust or Fur upon all that it lights, spoyling the moveables, tarnishing the Plate, Gildings, and Furniture, and corroding the very Ironbars and hardest Stones with these piercing and acrimonious Spirits which accompany its Sulphure; and executing more in one year, than exposed to the pure *Aer* of the Country it could effect in some hundreds."[9] Sulfur dioxide corrodes steel and destroys stone buildings and statuary. Cleopatra's Needle has deteriorated more in the ninety years it has been in New York City than during its previous three thousand years in Egypt. The burning of sulfur-bearing fuels, such as coal and oil, account for most sulfur oxides. Sulfur dioxide pollution has declined in the past decade, but it may emerge again as a major problem if coal burning increases.

Sulfur dioxide and dust, for centuries the major urban air pollutants, have recently been displaced by photochemical smog and carbon monoxide. The proliferation of the automobile and the switch from wood and coal to oil and gas fuels account for this shift. Photochemical smog, the Los Angeles type, arises when nitrogen oxides and hydrocarbons—products of automobile exhaust and petroleum refining—are exposed to intense sunlight and undergo a photochemical reaction, producing ozone and other chemically reactive compounds. It is for this reason that cities like Los Angeles, Denver, and Mexico City, with intense sunlight and congested traffic, are plagued by severe photochemical smog. The dirty brown haze of photochemical smog reduces visibility, irritates eyes and noses, and causes coughing and headaches. On bad days, some people with bronchitis, emphysema, and heart disease have difficulty breathing.[10] Unlike other pollutants, photochemical smog is often worse in the suburbs than in the city center. The transformation of nitrogen oxides and hydrocarbons emitted in morning rush hour traffic into smog occurs six to ten hours later, when the polluted air mass has moved away from the center.[11]

Carbon monoxide, an odorless, invisible killer, is most concentrated at the city center where cars, trucks, and buses clog narrow streets flanked by tall buildings, and most severe on weekdays during morning and afternoon rush hours. Breathing the carbon monoxide commonly found at major intersections, inside cars commuting in heavy traffic, and in tunnels and street canyons can cause headaches, drowsiness, and dizziness.[12] Policemen, taxi drivers, people working in open shops, and others who work on busy streets for extended periods flirt with carbon monoxide poisoning daily.[13] Cigarette smokers are especially vulnerable; smoking produces elevated carbon monoxide levels in the blood, so that even a moderate increase in atmospheric carbon monoxide affects smokers.[14] Heart patients are at greater risk of angina attacks in cities with carbon monoxide problems.[15]

Since gasoline-powered vehicles are the primary source of carbon monoxide, cities that rely mainly on the private automobile for transportation are prone to carbon monoxide pollution. In Los Angeles, for example, 97 percent of carbon monoxide stems from vehicle exhaust,[16] and high concentrations of carbon monoxide permeate extensive sections of the city daily. A Los Angeles commuter driving two hours a day in morning and afternoon traffic is exposed to enough carbon monoxide to elevate carbon monoxide blood levels to a "serious" level, a level of exposure sufficient to impair alertness, vision, and physical coordination.[17]

City dust is more than common dirt. Particles of lead, arsenic, asbestos, and cadmium are blown about in city air and breathed into the lungs. Many particulates, not necessarily poisonous in themselves, are host to toxic vapors adsorbed on their surfaces. Although automobile exhaust produces a relatively small proportion of the total suspended particulates in the ambient air above the city, these particulates have a substantial impact on health. They are not only

TABLE 2.2
*Sources of Major Air Pollutants*

| Source | Source Type | *Percentage of Emissions from Each Source by Pollutant*[a] CO | $SO_2$ | TSP | HC | $NO_2$ | Percentag All Emiss |
|---|---|---|---|---|---|---|---|
| portation | Mobile (line) | 83.5 | 3.0 | 8.8 | 40.7 | 39.6[b] | 55.8 |
| d vehicles alone | Line | (75.2) | (1.3) | (6.6) | (34.9) | (29.0) | (49.0) |
| mbustion | Stationary (point, area) | 1.1 | 81.8 | 38.7 | 5.4 | 56.1 | 22.1 |
| tric utilities alone | Stationary (point) | — | (64.2) | (27.0) | (0.3) | (30.6) | (14.6) |
| ial processes | Stationary (point) | 8.0 | 15.2 | 43.8 | 35.6 | 3.1 | 14.8 |
| aste disposal | Stationary (point) | 2.6 | — | 2.9 | 2.6 | 0.4 | 2.0 |
| aneous | | 4.8 | — | 5.8[c] | 16.0 | 0.4 | 5.3 |

Statistics from U.S. Bureau of Census, *Statistical Abstracts of the United States, 1979*, originally from U.S. Environm
on Agency, *National Air Quality and Emission Trends Report, 1977*

are absorbed and retained.[18]

The character and severity of air pollution problems varies from city to city. Tables 2.4 and 2.5 compare cities on the basis of the Pollutant Standard Index (PSI), the values of which are defined in table 2.3. New York has the worst carbon monoxide pollution in the United States.[19] In 1977 carbon monoxide reached unhealthy levels there nearly seven days out of every ten. Carbon monoxide is also the predominant air pollution problem in Denver, Chicago, Detroit, Philadelphia, Seattle, and Portland, Oregon. In Los Angeles, the carbon monoxide problem is overshadowed by the ozone in photochemical smog. Total suspended particulates are Buffalo's biggest problem; sulfur dioxide, Toledo's. A city's major industries, the types of fuels used to generate heat and electricity, and transportation patterns influence which specific pollutants predominate. A city's regional climate, physiographic setting, location of major pollution sources in relation to other land uses, and urban form all influence the distribution of air pollution within the city and help determine whether it is concentrated or dispersed. Los Angeles, for example, owes much of its air pollution problem to its sunny climate and its location between ocean and mountains. Its intense sunlight promotes the formation of photochemical smog; inversions and prolonged periods of high-pressure weather limit circulation. In New York City, where heavy traffic penetrates narrow street canyons, the carbon monoxide problem is primarily a consequence of transportation patterns and urban form.

## *Inversions and Stagnant Air*

The most infamous air pollution episodes, those that kill thousands and make headline news, are invariably caused by inversions. Normally air pollutants are borne up and away from the city on currents of warm air rising into cooler air above. Occasionally, the normal pattern of temperature stratification may be "inverted," with cooler air below and warmer air above: when a warm air mass moves in over a cooler one; when warm air flows over a colder surface; or when the air near the ground is cooled from below at night. The cooler air, unable to rise into the warmer air above, is trapped near

TABLE 2.3

*Definition of Pollutant Standard Index (PSI) Values*

| | | *Pollutant Level* | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *PSI Index Value* | *Air Quality Level* | *TSP (24-hour), μg/m³* | *SO₂ (24-hour), μg/m³* | *CO (8-hour), μg/m³* | *O₃ (1-hour), μg/m³* | *NO₂ (1-hour), μg/m³* | *General Health Effects* | *Cautionary Statements* |
| 500 | Significant harm | 1000 | 2620 | 57.5 | 1200 | 3750 | | |
| 400 | Emergency | 875 | 2100 | 46.0 | 1000 | 3000 | Premature death of ill and elderly. Healthy people will experience adverse symptoms that affect their normal activity. | All persons should rema indoors, keeping wi dows and doors close All persons should mi mize physical exerti and avoid traffic. |
| 300 | Warning | 625 | 1600 | 34.0 | 800 | 2260 | Premature onset of certain diseases in addition to significant aggravation of symptoms and decreased exercise tolerance in healthy persons. | Elderly and persons wi existing diseases shou stay indoors and avo physical exertion. Ge eral population shou avoid outdoor activity. |
| 200 | Alert | 375 | 800 | 17.0 | 400[a] | 1130 | Significant aggravation of symptoms and decreased exercise tolerance in persons with heart or lung disease, with widespread symptoms in the healthy population. | Elderly and persons wi existing heart or lur disease should stay i doors and reduce phys cal activity. |
| 100 | NAAQS | 260 | 365 | 10.0 | 240 | | Mild aggravation of symptoms in susceptible persons, with irritation symptoms in the healthy population. | Persons with existing hea or respiratory ailmen should reduce physic exertion and outdo activity. |

SOURCE: U.S Council on Environmental Quality, *Tenth Annual Report*, 1979.

[a] 400 μg/m³ was used instead of the $O_3$ Alert Level of 200 μg/m³.

(PSI) Air Pollution Data, 1975–77

| Severity Class | SMSA | Number of "Unhealthful" Days (PSI over 100) |  | Number of "Very Unhealthful" Days (PSI over 200) |  |
|---|---|---|---|---|---|
|  |  | Three-Year Average | Minimum-Maximum Annual Days During Three Years | Three-Year Average | Minimum-Maximum Annual Days During Three Years |
| I (More than 150 days of PSI readings above 100) | Denver | 157 | 143–182 | 30 | 20–37 |
|  | Cleveland | 225[a] | 228–229 | 41[a] | 12–59 |
|  | Los Angeles | 264 | 253–272 | 132 | 117–142 |
|  | Louisville | 150 | 104–185 | 20 | 14–31 |
|  | New York | 273[b] | — | 87[b] | — |
|  | Riverside | 193 | 174–224 | 106 | 88–122 |
| II (100–150 days of PSI readings above 100) | Anaheim | 120 | 95–134 | 38 | 17–58 |
|  | Chicago | 139 | 81–195 | 21 | 14–31 |
|  | Philadelphia | 103 | 79–143 | 12 | 7–19 |
|  | St. Louis | 123 | 97–141 | 21 | 13–33 |
|  | Washington, D.C. | 110 | 74–147 | 16 | 7–26 |
| III (50–100 days of PSI readings above 100) | Baltimore | 64[a] | 49–79 | 18[a] | 10–25 |
|  | Houston | 54 | 48–64 | 9 | 4–12 |
|  | Jersey City | 74[b] | — | 8[b] | — |
|  | Nashville | 59 | 39–76 | 3 | 1–5 |
|  | Portland | 78 | 70–83 | 7 | 3–13 |
|  | Salt Lake City | 82 | 61–110 | 18 | 9–25 |
|  | San Diego | 59 | 45–74 | 6 | 4–9 |
|  | San Jose | 58 | 42–81 | 8 | 0–21 |
|  | Seattle | 86 | 73–95 | 5 | 4–5 |
| IV (25–50 days of PSI readings above 100) | Buffalo | 41 | 31–51 | 7 | 3–11 |
|  | Cincinnati | 41 | 20–63 | 2 | 1–4 |
|  | Dallas | 26 | 18–35 | 1 | 0–2 |
|  | Dayton | 33[a] | 29–37 | 1[a] | 1–2 |
|  | East Chicago | 29 | 27–31 | — | — |
|  | Hartford | 34 | 25–41 | 6 | 3–8 |
|  | Indianapolis | 33[a] | 17–49 | 2[a] | 1–3 |
|  | Milwaukee | 35 | 32–40 | 8 | 7–8 |
|  | Sacramento | 26 | 19–38 | 1 | 0–3 |
|  | San Francisco | 33 | 24–45 | 1 | 0–2 |
| V (0–25 days of PSI readings above 100) | Akron | 14[b] | — | 0[b] | — |
|  | Grand Rapids | 3[a] | 1–8 | 0[a] | 0 |
|  | Honolulu | 0[a] | 0–1 | 0[a] | 0 |
|  | Kansas City | 12 | 5–23 | 3[a] | 0–8 |
|  | Memphis | 24 | 19–24 | 3 | 0–7 |
|  | Norfolk | 13 | 9–16 | 1 | 0–2 |
|  | Oklahoma City | 11[b] | — | 0[b] | — |
|  | Rochester | 5 | 2–8 | 0 | 0 |
|  | San Antonio | 10[a] | 8–11 | 0[a] | 0 |

---

Number of Days Pollution Standard Index (PSI) Exceeded[a]

|  | New York |  |  | Los Angeles |  |  | Denver |  |  | Chicag |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
| lutant | 100–200 | 200–300 | 300+ | 100–200 | 200–300 | 300+ | 100–200 | 200–300 | 300+ | 100–200 | 200–300 |
| O | 165 | 82 | 0 | 69 | 21 | 0 | 109 | 18 | 0 | 89 | 1 |
|  | 21 | 3 | 0 | 66 | 96 | 0 | 6 | 0 | 0 | 18 | 5 |
| SP | 0 | 1 | 1 | 1 | 0 | 0 | 7 | 2 | 1 | 13 | 10 |
| O$_2$ | — | — | — | — | — | — | — | — | — | 0 | 1 |
| $_2$ | — | — | — | — | — | — | — | — | — | 3 | 0 |
| $_2$ + TSP | — | — | — | — | — | — | — | — | — | 0 | 1 |
| Total[b] | 186 | 86 | 1 | 136 | 117 | 0 | 122 | 20 | 1 | 123 | 18 |
| Total[c] |  | 273 |  |  | 253 |  |  | 143 |  |  | 142 |

ce: U.S. Council on Environmental Quality, *Tenth Annual Report*, 1979.

SI 100–200: "unhealthful"; PSI 200–300: "very unhealthful"; PSI 300+: "hazardous."

Number of days within each category

tal number of days PSI exceeded 100.

the ground for hours or even days and all the city's poisonous emissions with it. The longer the inversion persists, the higher the concentrations of air pollution within the city. Inversions are occasional and brief events in all cities, and frequent or prolonged ones in cities with a topographic or climatic predisposition. Inversions can form at the scale of an entire metropolitan region, or at the scale of a street canyon (see figure 2.1).

Inversions are most pronounced in clear, calm weather, and common and prolonged in cities like Los Angeles and Tucson with climates characterized by frequent, stable high-pressure systems. Like London, Los Angeles has an air pollution problem as old as its settlement by humans. Juan Rodriguez Cabrillo named Los Angeles "the Bay of Smokes" in 1542 after observing the smoke from Indian fires trapped by an inversion.[20]

Inversions are common in valleys and in valley cities like Cincinnati or St. Louis. Valley inversions form on clear, calm nights, when dense, cool air pools on the valley floor and the air temperatures remain up to 10° Fahrenheit warmer on adjacent hillsides,[21] and although frequent, usually lift by midday. In Stuttgart, West Germany, an industrial city in the Neckar River valley, inversions occur on the average of 247 days per year.[22] When an industrial city is located in a valley, the valley becomes a pollution basin. One of the most famous air pollution disasters in the United States occurred in Donora, Pennsylvania, a small city of steel mills and blast furnaces in a valley surrounded on all sides by steep hills. In 1948, a thermal inversion put a lid over the valley for three days. By the end of the third day,

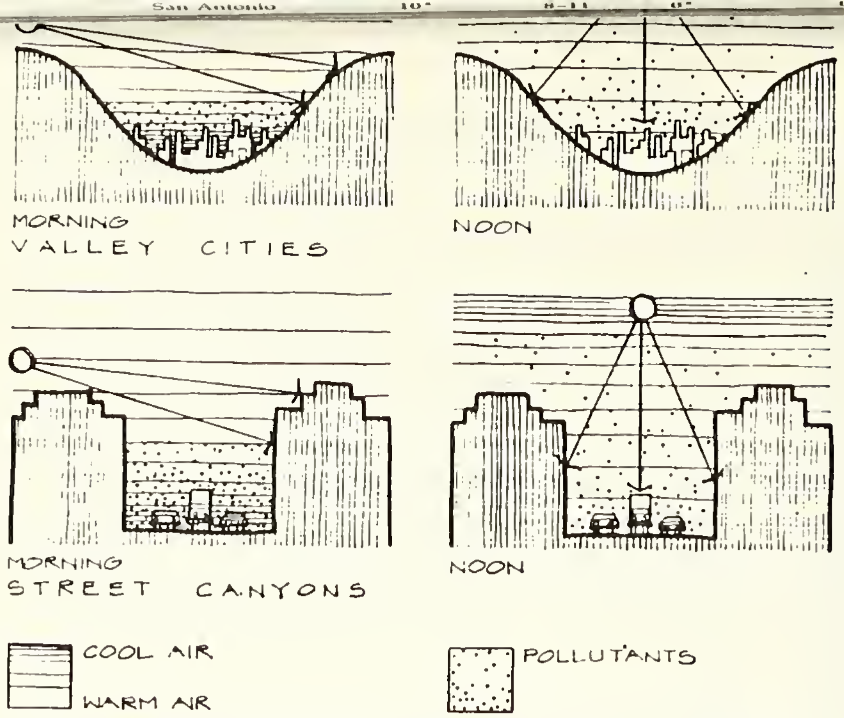


*FIGURE 2.1*
The formation of inversions in valley cities and street canyons, both a result of the same processes.

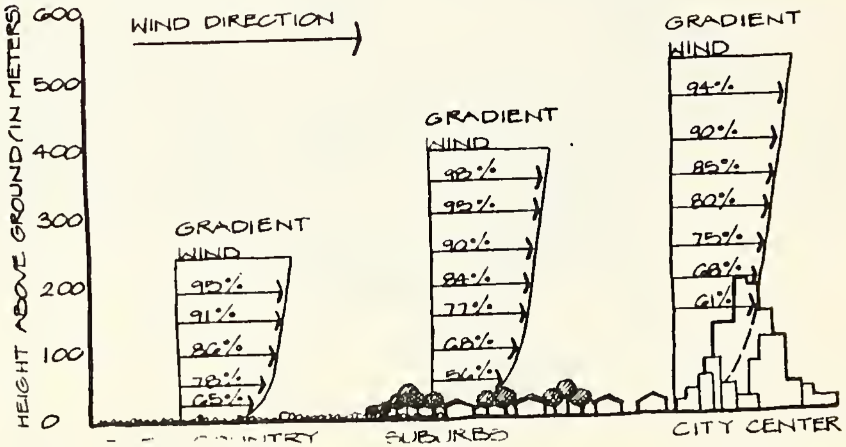
nearly 6,000 people were ill, including more than 60 percent of the elderly residents, and 20 people were dead.[23]

To ignore air pollution considerations when designing cities that experience frequent inversions or periods of stagnant weather is irresponsible. Yet in Tucson and Los Angeles, work and home are widely separated, and both cities are poorly served by public transport, necessitating heavy automobile traffic. New factories and freeways are often located in valleys, instead of on higher elevations where they would be better placed. Planners frequently locate new industries on the basis of prevailing wind directions rather than wind directions under inversions, with the result that pollutants may be swept back over the city when an inversion does occur. In Baltimore, for example, 52 percent of all winds are from the southwest to northwest, but during stagnation periods, 41 percent of the winds come from the east to south.[24]

Winds determine whether the poisons at street level are rapidly dispersed and diluted or linger to concentrate to dangerous levels. Contrary to the subjective experience of city dwellers, buffeted daily by gusty turbulence, the city is actually less windy than the surrounding countryside. Most gusts felt by urban pedestrians are swirling masses of stationary air which trap and concentrate pollutants, rather than dispersing and diluting them.

The city presents a rough surface to the wind. Building peaks and street canyons, with their abrupt changes in shape, height, and orientation, place a frictional drag on the layers of air closest to the city's surface, slowing them down (figure 2.2). Whether regional winds dip below roof level to penetrate the city depends on the orientation and continuity of open spaces and streets. Indeed, the precise pattern of air flow through and within an individual city is unique and complex. Winds accelerate along streets oriented parallel to the direction of the wind; eddies are created in streets running at right angles to the wind; and calms persist at the bottom of deep courtyards and other small, confined spaces. Gusts and lulls, eddies and jetlike winds, occur simultaneously within several hundred yards of one another or from one second to another in the same

*FIGURE 2.2*
Reduction of wind speed over city and suburb, expressed here as percentage of gradient winds, those winds uninfluenced by surface friction. Winds, slowed by the complex building surface in cities, may be half as strong at ground level as in level countryside.



of changing regional wind speeds and directions with surface topography, the aerodynamic shapes of nearby buildings, the size and shape of the space surrounding them, and the form of the city upwind.

The overall form of a city that is laid out without regard to wind patterns not only increases the likelihood that air pollutants will concentrate, but also intensifies the discomfort of city residents by permitting the formation of a phenomenon known as the urban heat island.

## *The Urban Heat Island*

The city is hotter than the surrounding countryside during part of the day and much of the night. Summer nights bring little relief to the city, even when the surrounding suburbs have lost the day's heat. After sunset on a clear night, the temperature difference between city and suburbs is frequently 9° F and may reach 20° F.[25] The results, in hot weather, are higher air conditioning bills, greater discomfort, and in a prolonged heat wave, more strokes and death. The densest parts of the city are the hottest; temperatures fall as density decreases and drop sharply at the limits of continuous urban development.

The urban heat island is a universal characteristic of city climate, clearly visible on a map of nighttime temperatures for any metropolitan region (see figure 2.3). Several factors account for the urban heat island. In the city, concrete, stone, brick, and asphalt replace the natural plant cover of the countryside. These materials absorb heat more quickly and store it in greater quantities than the plants, soil, and water that make up forests, fields, and ponds. All day long, pavement, walls, and roofs absorb and store incoming solar radiation as heat. Although plants and water absorb solar radiation also, much of that energy is expended in evaporation and transpiration—resulting in heat loss rather than gain. City activities are also a source of heat; much of the heat results from combustion, which is the mainstay of transportation, and from the activities of manufacturing, heating buildings, and generating electricity. The combined metabolic processes of all the people who live in the city adds to that total, a phenomenon appreciated by anyone who has ridden a crowded bus or elevator.

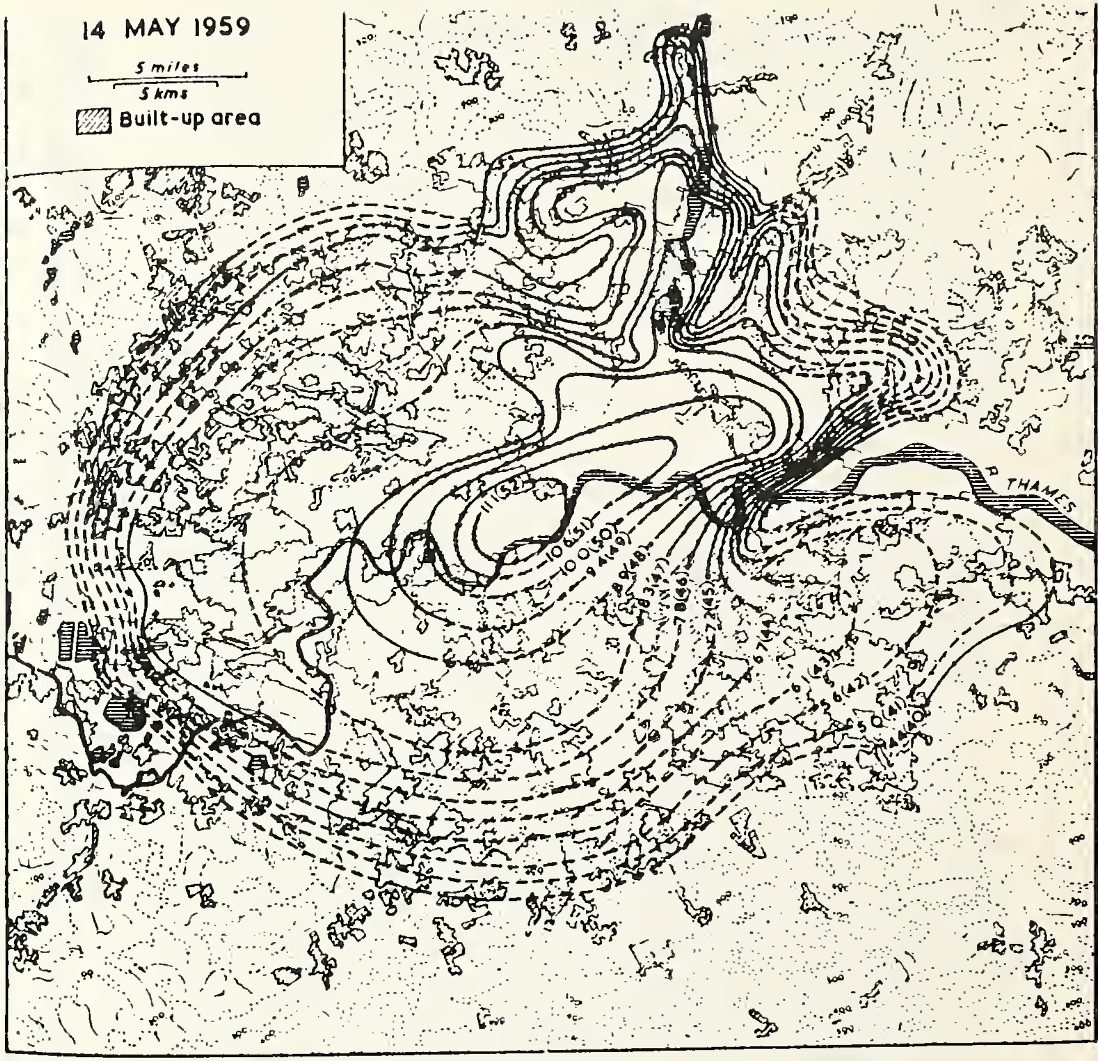


*FIGURE 2.3*
Temperature contours in greater London (each contour represents a temperature change of 1°F.) clearly demonstrate the origin of the term "urban heat island." The innermost circle, the center of London, is 12 degrees Fahrenheit hotter than the outermost circle at the metropolitan outskirts.

The disparity in air temperature between the city center and rural periphery is most pronounced on clear, calm nights a few hours after sunset. On such nights, the countryside loses heat rapidly to the cloudless sky. The city cools off more slowly: it has absorbed more heat, and the reradiation of that heat to the night sky is inhibited by parallel building walls. By morning, the temperature differcommon city microclimates demonstrate many of these variations: street canyons, paved plazas, and parks.

The street is central to the lives of urban poor and rich alike. A child in Harlem plays stickball in the street; adults congregate on the stoop. A child on Park Avenue rides his tricycle up and down the sidewalk under the doorman's watchful eye; his parents jog beside morning traffic. Lives are lived out on the street—playing, strolling, walking, driving, strutting, hustling, sitting, watching. The street is the city's life line and stage. It could be a delight. Today it is one of the unhealthiest urban environments.

Poisonous gases hang in the air above the street and toxic dust coats the roadway and sidewalk. Cars, buses, and trucks congest the streets, accelerating and braking, emitting streams of carbon monoxide, nitrogen oxides, and bits of lead and unburned fuel. The stop-and-go traffic characteristic of a busy street produces more pollutants than traffic moving smoothly at constant speed along the highway because the concentration of exhaust waste is greatest at an irregular rate of combustion. Oil droplets from the engines are turned into a fine aerosol; asbestos is rubbed from brake linings; the street pavement literally grinds the rubber from rolling tires into a fine dust.

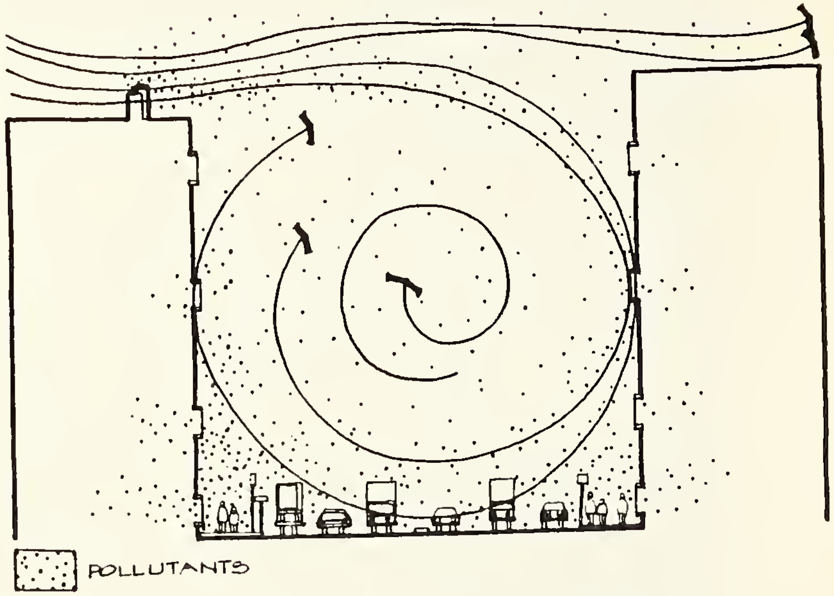
A downtown street canyon lined by tall buildings not only generates a high level of noxious substances, but also inhibits their dispersion. The volume and speed of vehicular traffic determine to what degree the air at street level is contaminated. Distance from the road and ventilation determine the distribution of pollutants and the degree to which they concentrate in a given area. Airborne particles of lead can decrease 50 percent in the interval between the road's edge and 50 meters (164 feet) away.[32] The sidewalk and building entries in a street canyon are located within the zone of highest accumulation.

A local inversion may form at the bottom of a shady street canyon in the morning, trapping the exhaust from rush hour traffic at breathing level. Unless dissipated by winds, the inversion persists until the midday sun reaches the street and warms the surface and air at ground level. By that time, concentrations of carbon monoxide and other poisons may have reached levels sufficient to affect anyone exposed to this air for as little as an hour. Pedestrians, traffic cops, street vendors, and taxi drivers are not the only ones affected. If the intake shafts for subways or air conditioning vents for build-

third, and fifty-fourth floors of one Toronto office building showed that carbon monoxide concentrations were only 28 percent less on the first floor than on the sidewalk, 37 percent less on the third floor, and over 60 percent less on the fifty-fourth floor.[34] Carbon monoxide concentrations in the lower floors of buildings near congested urban streets can aggravate heart disease.[35]

The ventilation of street canyons depends upon the width of the street, the heights and shapes of surrounding buildings, the street's orientation in relation to prevailing wind directions, and the overall pattern of winds in the surrounding city (see figure 2.5). When streets are aligned parallel to the direction of the wind, wind speeds may flush out the air at street level, carrying off fumes and dust. Streets perpendicular to the prevailing winds, however, receive little or no effective ventilation. Turbulence at street corners does not disperse pollutants, but merely swirls them around in the air, and the stagnant air in midblock permits them to collect. Downdrafts at the base of tall buildings, swooping down from rooftops, bring

*FIGURE 2.5*
Pattern of air pollution in a street canyon, a function of wind direction and shape and size of the canyon. Note that smoke emitted at rooftop may be swept down to street level.

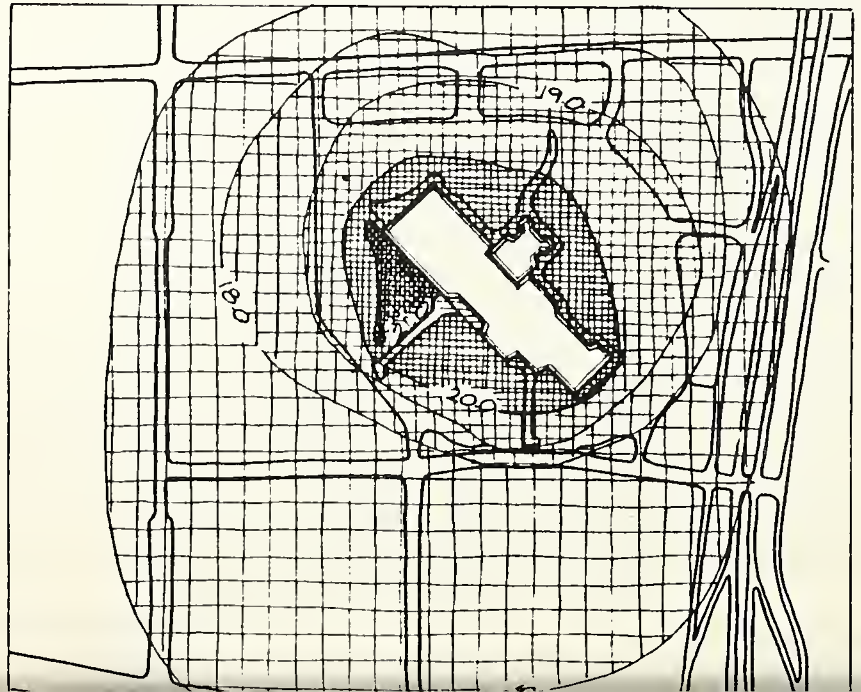


ence between city and country is minimal and may even be reversed, but by midafternoon, the city is hotter again.

The city's central business district, with its tall, densely spaced buildings on narrow streets with confined courtyards, typically forms the heat island's core. Here the thermal capacity of buildings and pavement is greatest and the air circulation poorest. Landscaped parks and river valleys, on the other hand, are relative cold spots within the heat island.

Urban form and density influence the intensity of the heat island more than does city size. Areas of similar urban development type and density in Leicester, England (population 270,000) and ninety miles away in London (population 8,250,000) have experienced the same excess of temperature over nearby rural areas on the same nights.[26] In fact, mini heat islands have even been measured in small courtyards and shopping malls (figure 2.4).[27]

*FIGURE 2.4*
Shopping mall heat island, generated by dense buildings and surrounding parking lot. Here, air above the center of the parking lot (innermost circle) is 4 degrees centigrade (7.2 degrees Fahrenheit) hotter than in a suburban neighborhood one block away (outermost circle).



Wind speed, cloud cover, and atmospheric stability also affect the shape and intensity of the urban heat island. A breeze displaces the heat island downwind; a strong wind may disperse it entirely. The wind speed required to disperse the heat island varies with city size; London requires a wind of 12 meters (39 feet) per second whereas Reading, England, with a population of 120,000, only requires a wind of 4.7 meters (15.4 feet) per second.[28] Under cloudy conditions, less solar radiation reaches the ground, and the heat island is, therefore, less pronounced. Under inversion conditions, when the atmosphere is stable and heat is inhibited from rising, the heat island is intensified. The shape and intensity of the heat island fluctuate within a city in response to seasonal and annual changes in these variables.

The heat island may have a beneficial or a detrimental effect on energy conservation. The heat island reduces winter heating bills, but in warm climates these savings may be offset by the increased need for air conditioning in summer. Air conditioning requires more energy than heating and, furthermore, it produces heat, aggravating the heat island. A study of twelve cities in different parts of the United States indicated that heating was required on 8 percent fewer days in the city than in the outlying region, but that air conditioning was required on 12 percent more days.[29]

The urban heat island causes excess deaths in the city during heat waves. During a heat wave in the summer of 1966 the normal death rate was exceeded by 50 percent in New York City and 56 percent in St. Louis.[30] Persons over the age of 80 and those suffering from hypertension, heart and lung disease, and diabetes were the most likely to die from heat stress. Deaths were most frequent among the poor in the densest parts of the city and least frequent among the most affluent and in the suburbs. Several factors contribute to this. Air conditioning is less common among the poor, and pavement radiates as much as 50 percent more heat than does grass. People in the densest parts of the city are therefore subject not only to higher air temperatures but also to the additional heat radiated from surrounding pavement and buildings.[31]

## *A Mosaic of Microclimates: Street Canyons, Plazas, and Parks*

Every city is composed of a mosaic of radically different microclimates, which are created by the same processes that operate at the citywide scale. The same phenomena that characterize the urban me-

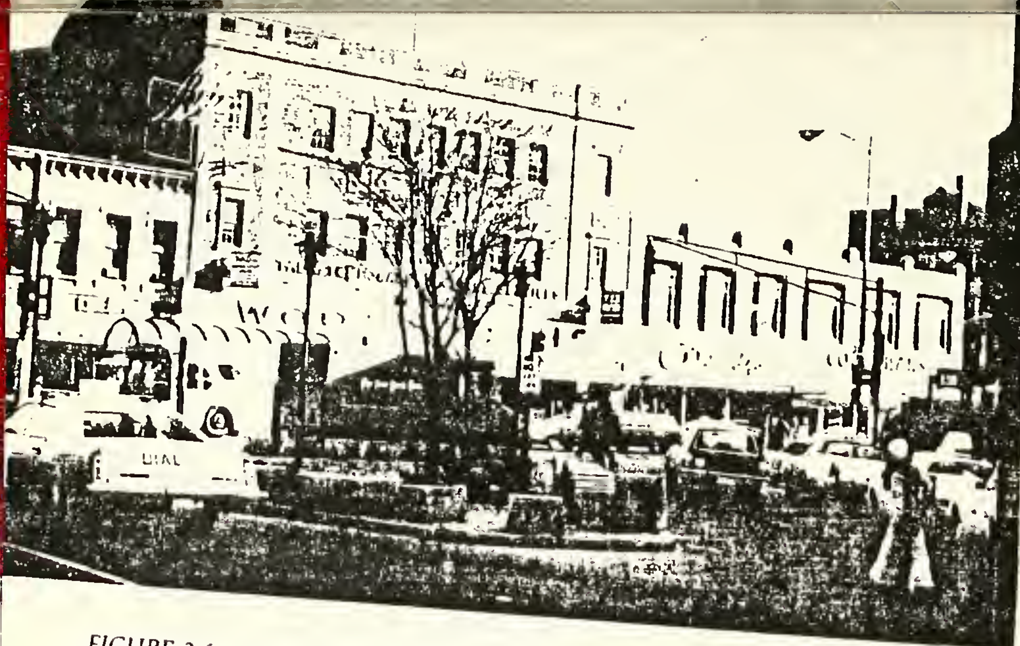


*FIGURE 2.6*
A traffic island park in Cambridge, Massachusetts, enveloped in exhaust from buses, cars, and trucks. Anyone sitting there inhales a poisonous atmosphere.

smoke from chimneys to ground level and stir up dust from street and sidewalk.

Busy city streets are not suitable locations for sitting areas, playgrounds, sidewalk cafes, or vegetable gardens until the streetside air is improved or unless the area is well ventilated and set back from the street. Central Square (figure 2.6), a congested intersection in Cambridge, Massachusetts, exemplifies where not to put a park. In the midst of a five-way intersection is a triangular traffic island fitted with benches and two trees—ergo, a park. And surrounding that pitiful park are three traffic lights, three bus stops, and a taxi stand. At any time lines of cars and trucks stop at the lights, taxicabs with motors idling and a bus or two stand nearby—all emitting streams of foul air. On a windless, stuffy, summer day, carbon monoxide and nitrogen oxides, though invisible, permeate the air over the tiny park. Dust of lead and hydrocarbons coats the bricks and benches. The park is an oven, baked in heat from surrounding cars and pavement. It was built for local residents, mostly poor and elderly, who live in nearby boarding houses and small apartments. A summer day

[illegible] sitting in the tiny triangle, barely moving, looking slightly disoriented. Is their confusion and lethargy due to senility? Or is it carbon monoxide poisoning? Such well-meaning but misguided attempts to provide parks for people in the poorest and densest parts of the city are found in nearly every city. Central Square would be better off with a grove of trees on the triangle rather than the sham of a sitting area.

Urban plazas should be amenities; most are not. Crowds throng the most successful, filling every sittable niche at lunch hour; the failures are deserted. Success or failure has much to do with comfort; unfortunately, comfort is usually a minor concern in the design of outdoor places, if it is considered at all. A barren plaza at the foot of a tall building can be one of the most uncomfortable places in the city, and may even be dangerous.

Winds sweep down and around adjacent buildings and blast unchecked across an open plaza. The winds in plazas and in arcades beneath tall buildings may accelerate to quadruple the speed in protected streets nearby. Since wind force increases exponentially with speed, wind four times as fast hits pedestrians with sixteen times the force.[36] Two elderly women died in Britain in one year from head injuries suffered after being knocked over by winds at the base of a tall building.[37] Plazas are frequently too shady in winter and exposed to too much sun at the hottest time of day in summer.

City Hall Plaza is one of Boston's major outdoor public spaces, a grand plaza of brick surrounding a striking, modern city hall. Its monumental scale sets off the monumental building. The visual effect is enhanced by the federal government buildings that face on it—it is Boston's Government Center. But the plaza, however impressive as a setting for architecture and a center for government, is a disaster for physical comfort. In summer, it offers no shade to relieve the heat generated by the sun and augmented by hot pavement. Only when there are sea breezes from the nearby waterfront is the plaza bearable. During the long Boston winter, the plaza is a no man's land. Winds from the harbor rip across the unbroken expanse of brick. There is no protection from driving snow and rain. The plaza's size, slope, and steps defy attempts at snow removal. The walk of several hundred feet across the plaza from the Government Center subway station to City Hall or to the federal buildings is an ordeal not lightly undertaken in winter's rain and snow or spring slush. The effect of climate has negated the intended symbolic accessibility of government. Granted, there are equally important concerns for designers—both functional and aesthetic—as comfort, but if a place is sufficiently uncomfortable, that discomfort may undermine all other considerations. Boston has a long winter and a short spring and fall. The design for any public space should respond to those basic climatic facts. However beautiful and expansive, City Hall Plaza is misplaced in Boston; its form is suited to a more benign climate like that of Italy or California.

In contrast to the plaza, a shady park absorbs less heat during the day and loses it more rapidly after sunset. The microclimate of a large, tree-filled park resembles that of a woodland. It shows up as a "cold spot" on an infrared photograph taken from the air at night. Rock Creek Park in Washington, D.C. can be more than 5 degrees centigrade cooler at night than adjacent residential neighborhoods and over 9 degrees cooler than the central business district.[38] Although daytime air temperatures are similar to those above adjacent city streets, the park feels cooler because there is more shade, less glare, and less heat radiated from lawn and trees. The climatic effect of a shady park extends to adjacent streets. A tree-lined street adjacent to a park seems cooler in summer than a treeless street two blocks away. A landscaped park also has cleaner air than the surrounding city, in part because the park is not emitting air contaminants, but also because the leaves and twigs of trees and shrubs filter out dust from the air. Nineteenth-century urbanists created large landscaped parks in the inner city as "lungs for the city." Today they are disappearing or in decline, victims of slashed municipal budgets and easy prey to public building programs in search of open land. New parks, completely paved and with few, if any, plants, are replacing them. There is little to distinguish these "parks" from the city around them, either climatically or aesthetically.

Many of the social costs of continuing to discount climate and air quality in city design are already manifest: increased mortality among the elderly, the sick, and the very young; lead poisoning among children; degraded health of city residents and workers; increased energy demands; and property damage. Without intervention, these problems will intensify.

Despite cheerful predictions that air quality in most cities will meet national standards by 1987, existing programs, on which such predictions are premised, are faltering. Industry complains of the high cost of pollution control, and a society faced with unemployment and an uncertain economy weighs the cost of air quality against jobs. Oil shortages and rising prices encourage many cities

sions alone could solve carbon monoxide and ozone problems, but these rely upon the compliance of millions of individual car owners, each of whom thinks his own role insignificant. Releasing a canister of poison gas on a sidewalk is a criminal act, yet those who destroy the emission control devices on their cars, who burn leaded gasoline, who leave their engines running when parked at the curb are engaged in activities no less irresponsible.

The lessons of history are clear. In economic crisis or fuel shortage, in the face of short-term self-interest, concern for air quality is abandoned. Attainment of better air quality must not depend on the control of emissions alone, but should be coordinated with a city design that encourages the dispersion and filtration of pollutants and improves the overall city climate. Most metropolitan plans and new building projects exacerbate air pollution and accentuate the worst problems of city climate. Industry and highways are located in basins with limited air circulation. More and more cars are funneled into narrow, downtown street canyons by new, larger expressways. Schools, playgrounds, small sitting areas, and intake vents for air conditioners are all placed along busy streets. New buildings block ventilating winds, and create stagnant air pockets and hurricane force downdrafts. Parks are built with more pavement and fewer trees, fountains, and pools; and they are located without regard for their potential to improve air quality and comfort.

Meanwhile, urban designers import Italian piazzas to Boston and Karachi; architects design the same new building forms in New York, Jeddah, Nairobi, and Hong Kong, with interior climates maintained by furnaces and air conditioners. To manipulate the city's climate for health, comfort, and energy conservation is imperative, yet the designers and planners of modern cities seldom do so. The builders of ancient cities addressed these issues with more concern and more skill.

against jobs. Oil shortages and rising prices encourage many cities

# Improving Air Quality, Enhancing Comfort, and Conserving Energy

THE BUILDERS of ancient cities recognized the benefits of adapting urban form to climatic conditions. The Roman architect Vitruvius cautioned his contemporaries of the first century A.D. to give careful consideration to sun and winds when designing new towns in outlying provinces:

> The town being fortified, the next step is the apportionment of house lots within the walls and the layout of streets and alleys with regard to climatic conditions. They will be properly laid out if foresight is employed to exclude the winds from the alleys. Cold winds are disagreeable, hot winds enervating, moist winds unhealthy. We must, therefore, avoid mistakes in this matter and beware of the common experience of many communities. For example, Mylitene in the island of Lesbos is a town built with magnificence and good taste, but its position shows a lack of foresight. In that community when the wind is south, the people fall ill; when it is northwest, it sets them coughing; with a north wind they do indeed recover but cannot stand about in the alleys and streets, owing to the severe cold. . . . If the streets run full in the face of the winds, their constant blasts rushing in from the open country, and then confined by narrow alleys, will sweep through them with great violence. The lines of houses must therefore be directed away from the quarters from which the winds blow, so that as they come in they may strike against the angles of the blocks and their force thus be broken and dispersed.[1]

of seventeenth-century London for the benefit of "health, profit and beauty." He understood the effect of winds, topography, and air temperature on the dispersion of pollutants. His recommendations ranged from the development of alternative fuel sources to the application of emission and land-use controls.[2]

Traditional "primitive" building forms and village plans vary from climatic zone to climatic zone, reflecting the stresses posed by each. In hot, humid climates, overhangs provide shade. Buildings are open and raised off the ground and houses are spaced widely to promote ventilation. In hot, arid climates, thick stone or earthen walls moderate daily fluctuations in temperature; small windows and doors limit the penetration of sunlight and prevent the escape of cool interior air. Buildings are huddled in each other's shade; plants are nurtured in small, enclosed courtyards.

Many solutions to air pollution, energy conservation, and comfort available today have been applied for centuries, if not millennia. Their success and similarity derive from an understanding of the processes governing sun, wind, and the production of air pollutants. Today these processes are far better understood than ever before, but that knowledge is infrequently applied. A few contemporary parks and plazas, like Paley Park at 53rd Street near Fifth Avenue in New York City, have incorporated the most basic principles of climatic comfort—a fact that contributes to their overwhelming social success. They rank with the best historic examples and are worthy of study. As of yet, only a handful of cities—Stuttgart, West Germany, and Dayton, Ohio, among them—have developed comprehensive metropolitan designs based on the more refined information that is now available. Although their specific solutions may not be transferable to another city, the basic notion will always apply: the key is an understanding of process.

## *Sun, Winds, and Emissions*

Buildings gain and lose heat, and pollutants are concentrated or dispersed by the same mechanisms everywhere—in Tokyo or Tucson, at the scale of the city or the street corner. Factories, power plants, and incinerators; cars, trucks, and buses; and thousands of small commercial and domestic furnaces all contribute to the city's air pollution.

Understanding how pollutants are emitted is the first step toward control and dispersal. There are three types of sources—point, line, and area—each characterized by the variety and quantity of pollutants produced, and the likely pattern of their dispersion. A point source, such as a power plant or factory, can be pinpointed and monitored. One can measure the specific pollutants and their quantity, and the height, speed, and temperature of the pollutant plume. The dispersion of emissions under given meteorological conditions can be predicted, along with the size and shape of affected areas downwind. Point sources can be regulated during inversions and located in areas with good ventilation, distant from houses, schools, and parks.

A line source—a major traffic artery, for example—is less readily measured and controlled, but the types and amounts of pollutants produced on a road can be estimated, nevertheless, if daily fluctuations in traffic volume and speed are known. Dispersion from a line source is more difficult to predict than that from a point source, because line sources pass through different terrain and different types and densities of urban development. Pollutants disperse readily from an elevated highway, but accumulate when the highway is below grade or enclosed by adjacent buildings.

An area source is the sum of many small pollution sources, which remain anonymous by virtue of proximity or similarity of pollutants, an umbrella for all the small residential and industrial polluters of the city. Area sources account for a major portion of ground-level air pollution. Yet the individual sources cannot be singled out or measured. Area sources are, in consequence, extremely difficult to regulate, except by large-scale efforts such as changing the source of domestic heating for an entire area of the city. Many European cities have experimented with such "district heating," but U.S. cities have yet to apply it widely as a pollution control and energy conservation measure.

The city dissipates, deflects, intensifies, and generates air movement that can, if guided, disperse pollution. The complexities and contradictions of air flow in the city are difficult to master, but the reward is great since air movement can help dilute pollutants, enhance comfort, and conserve energy. Air movement is accelerated, slowed, or deflected as it moves over surfaces and around obstacles. The rougher the ground surface, the more the air is slowed down. An obstacle's density, the position and size of openings, its dimensions, shape, silhouette, and orientation determine at what spots

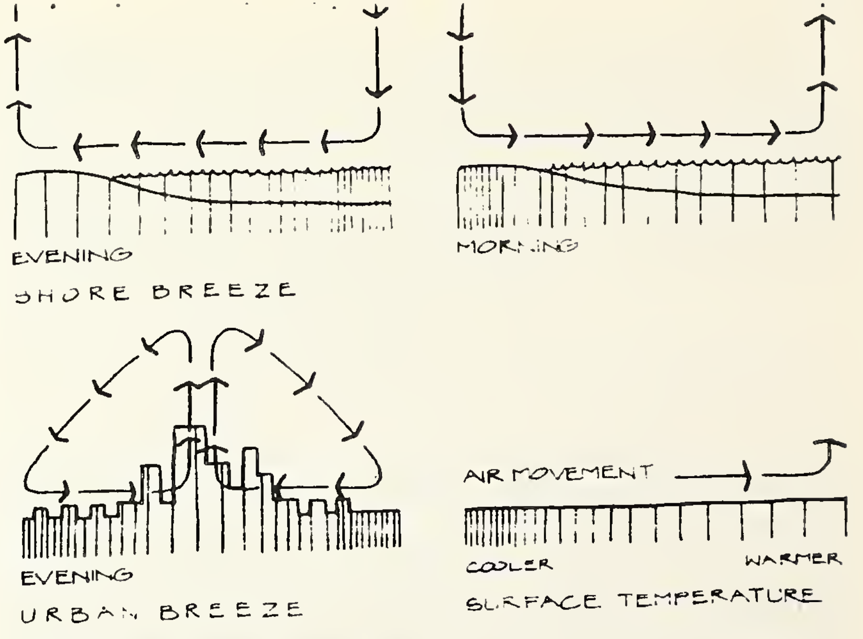


*FIGURE 3.1*
The daily cycle of thermal breezes along shorelines and in cities, both formed by the identical principle. As warm air rises over a heated surface (e.g., along the shoreline, the ground by day and the water by night), cooler air is sucked in to replace it, initiating a breeze in calm weather.

flected. The same principles hold true whether the obstacle is a single building, a group of buildings, or an entire city. Ventilation promotes air quality and summer comfort, but wind chill increases winter discomfort, and wind infiltration increases heating bills. When designing air movement, a balance must be struck between ventilation and comfort, and among the needs of different seasons.

Mild thermal breezes blow when regional winds are very light, generated by the difference in surface temperatures between the city and adjacent countryside, water bodies, or hillsides (figure 3.1). Urbanization in itself produces one type; the city's physiographic setting produces two others—shore and valley winds. When the urban heat island is most pronounced, it initiates a centripetal pattern of air flow from the cooler outskirts of the city to the hotter center. Air flows inward at a few feet per second until slowed, blocked, or heated, then rises, gradually cooling with height, and sinks back over the countryside.

Anyone who has lived by the shore of an ocean or large lake knows the daily pattern of onshore-offshore breezes. Land warms morning it blows from land to water. Since cities absorb more heat during the day than most rural land, they can accelerate this onshore wind, which may then penetrate more than a mile inland; since cities cool off more slowly, the offshore wind is probably less strong. Valleys have a similar daily cycle of air circulation—downslope breeze in the evening, which contributes to the formation of inversions, and upslope in the morning, when warm air rises from the valley floor up the hillsides.

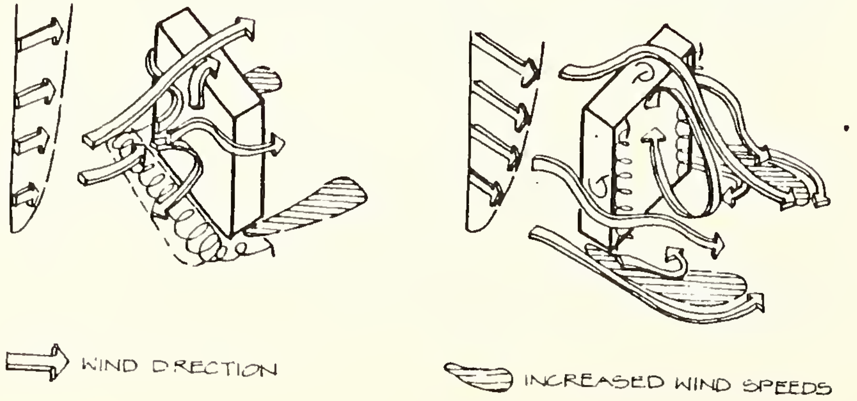
The movement of winds around a single building is well understood (see figure 3.2), and rules of thumb permit designers to predict its behavior. Wind moves in more complex ways through groups of buildings and in cities, however, and here there are very few rules of thumb. Fortunately, actual conditions can be duplicated in a wind tunnel by blowing air over a scale model; and therefore strategies for manipulating air movement in useful ways can be devised and tested.

Four major processes of energy transfer govern how buildings and people gain or lose heat: radiation, conduction, convection, and evaporation. Radiation is the primary source of heat gain. Radiation, evaporation, and convection are the major processes by which heat is lost.

Human comfort is a function of many factors: air temperature, air motion, humidity, metabolic rate, and clothing are primary. Air movement and mean radiant temperature vary more radically among different city environments than do air temperature and humidity, and can be more readily manipulated through urban design. The radiant temperature of surrounding pavement and walls can be decreased or increased by the promotion of shade or sun or by the selection of building materials for their thermal properties. The importance of controlling direct sunlight and wind is well recognized; the contribution of radiant heat to comfort is often overlooked. The body produces two to three times more heat walking than sitting—metabolic rate is controlled by decreasing or increasing activity. Requirements for comfort therefore vary with activities of different intensities.

What degree of air pollution or comfort is "acceptable" will depend on how many people use a place, when they use it, how long they stay there, and whether they can choose to avoid it. All the pollution problems of the city cannot be solved at once, but the most polluted and uncomfortable places, where many people spend much of their time, must be the first priority for any city.

*FIGURE 3.2*
The complex pattern of winds around an isolated building creates conditions where a person may sit in comfort in one spot and be knocked over by the force of the wind in a spot only twenty feet away. Wind speeds increase with height, so that winds hit different parts of the building with varying force.



## *Improving the Air along Streets and Highways*

The street cannot be avoided. Most people live, work, travel, and play on or near the street. Yet, as noted earlier, it is one of the most contaminated environments in the city, where air pollutants are often the least monitored and the least regulated.

Contamination on the street is caused by one major source: transportation; and so long as private automobiles are a major mode of urban transportation, pollution of the street will continue. Even so, better air quality on the street could be readily achieved. One can predict concentrations of specific pollutants at any point, given distance from roads, the width and height of the street canyon, and wind speed and direction. The fewer the cars, and the faster and more constant their speed, the fewer pollutants are produced. The greater the distance from the road, the fewer pollutants in the air. The wider and shorter the street canyon, and the fewer eddies and calms, the more pollutants are dispersed. In addition to emission controls and traffic regulations, street design standards could also reduce the pollutants emitted on the street and prevent their concentration. Judicious location of houses, businesses, and playgrounds could limit people's exposure.

There are precedents for public regulation of traffic, for standards for street design, and for zoning of land use, because streets and highways are public spaces, built, maintained, owned, and controlled by local, state, or federal government. A few public agencies could effect an enormous improvement in air quality by the enforcement of existing regulations and standards and the creation of a few new ones.

Planners have traditionally relied upon several strategies for reducing the emissions of air pollutants and their impact upon people: designing transportation networks and land use patterns to minimize travel and encourage the use of mass transit; enhancing smooth traffic flow; and protecting residential areas. Less attention has been given to the redesigning of the street or highway right-of-way and the regulation of adjacent land uses to encourage the dispersion of pollutants and limit exposure to them.

Traffic engineers distinguish among a hierarchy of roads—local streets, collectors, arterials, and expressways—each with characteristic functions, traffic speeds and volumes, size, and patterns of daily use. But basically there are only two types of roads, one for traffic and one for people. Efficiency of movement is paramount on expressways and arterials; access and the quality of the living environment should take precedence on collectors and local streets.

The social importance of the local city street was demonstrated in a study of a neighborhood in Baltimore that showed that neighborhood residents, predominantly lower-income blacks, preferred to socialize on the street than in nearby parks and playgrounds. Parks were frequently deserted, while the street front on an adjacent block was bustling, with people sitting, playing, or talking.[3]

> As the environments in which millions of families bring up their children, they might better be called "family streets." They introduce most of our children to our cities. These family streets should be sanctuaries for adults, an escape from the bustle of city life, a place for withdrawal and self restoration. But they also have a micropolitical role. They can become the stable units in a society riddled with placelessness, anonymity, alienation, and loneliness, remote from an often incomprehensible government. The street block is one focus for localism and decentralization of services. It is more compact, intense, and coherent than the neighborhood, and it has different kinds of problems. For all these reasons, its protection from intrusion and disruption becomes of value not just to local residents, but to cities and to society as a whole.[4]

Although local streets average up to 2,000 cars per day,[5] their important social functions are disrupted when there are more than 800

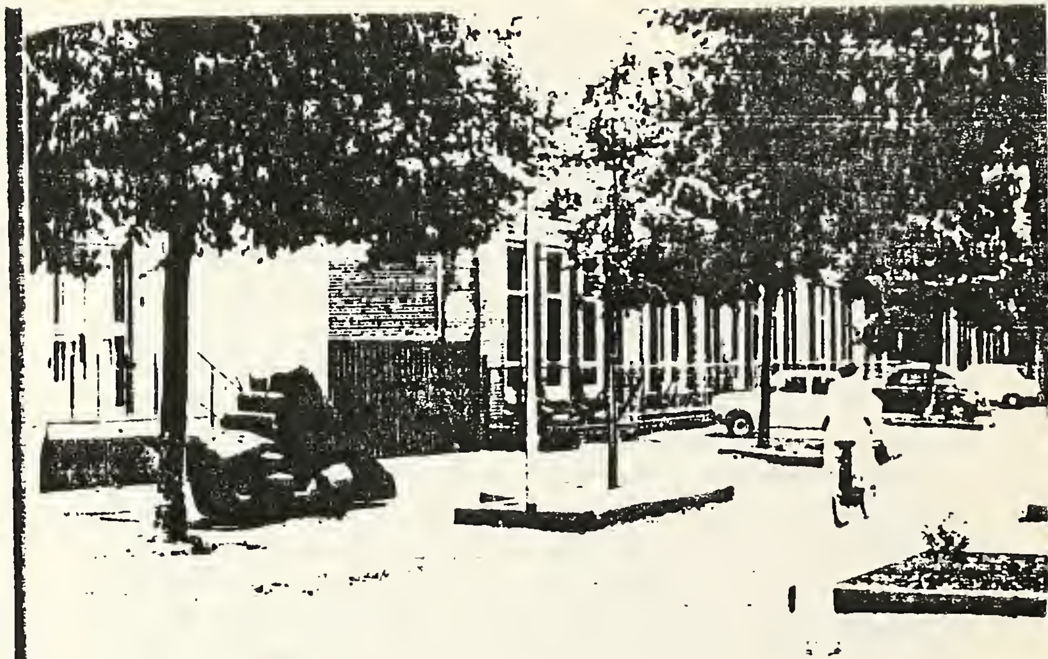


FIGURE 3.3
Dutch woonerf, a residential street with special traffic regulations where cars share the street with people and gardens.

name for such streets—"rat-runs." "Rat-runners" are drivers who weave their way across town through local streets in order to avoid traffic lights and congested streets. Reevaluating the role of the car on local streets is essential both to the improvement of health and comfort and to safety and quality of life.

The Dutch have developed a new type of street, the "woonerf," that enhances the social role of the residential street (figure 3.3). The woonerf ("residential yard" in Dutch) is a precinct with its own traffic rules: children and adults have precedence over cars and they use the entire roadway; cars must drive at a walking pace (about ten miles per hour). In the woonerf, distinctions between street and sidewalk are eliminated, and the resulting street space is shared by cars and pedestrians. The woonerf originated in Delft, where conventional streets were transformed by repaving them to eliminate curbs, by introducing obstacles like mounds, raised planters, and

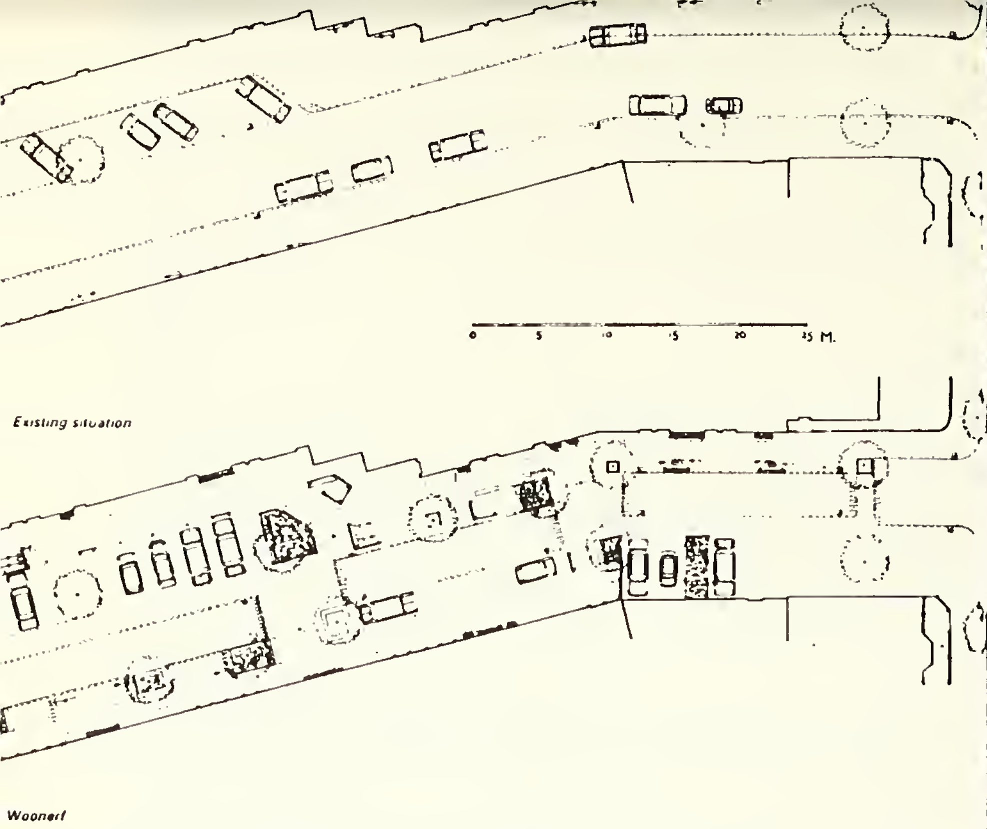


FIGURE 3.4
Plans show how existing streets are converted into woonerven. The roadway is narrowed, parking consolidated, and benches, trees, and gardens added.

woonerven in 200 cities and there is a long waiting list for future conversions.[7] German cities have implemented a similar concept called "Wohnbericht." Boston, an American city whose downtown streets resemble those of many European cities, has recently installed one woonerf in the South End, on Appleton Street. The conversion transformed Appleton Street from a shortcut to the Southeast Expressway into a social street for local residents. The decrease in traffic is dramatic, and the benefits to air quality on this residential street are likely to be pronounced.

Unlike local streets, expressways and arterial streets should promote the efficient movement of fast, heavy traffic, and should be designed to disperse air pollutants and limit people's exposure to them without impeding traffic movement. Arterial streets average 24,000 vehicles per day, and they generate a zone of air pollution

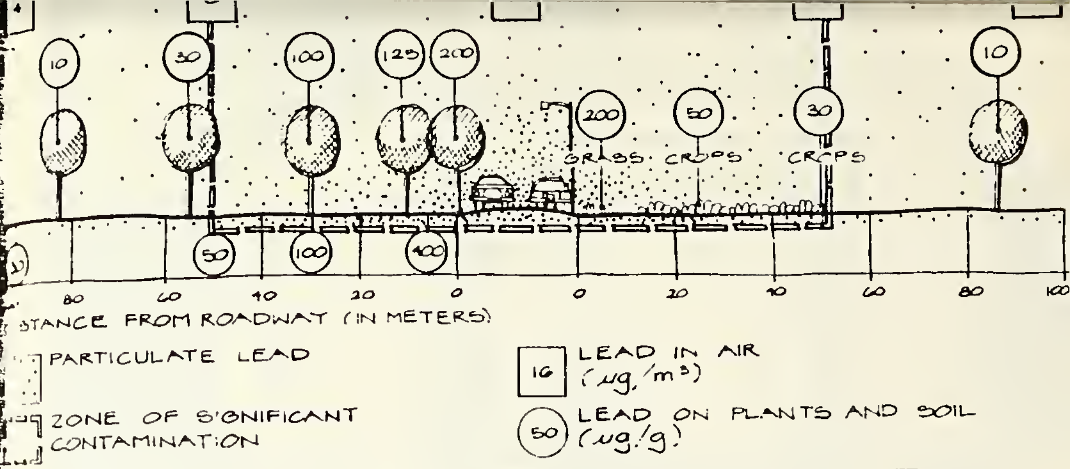
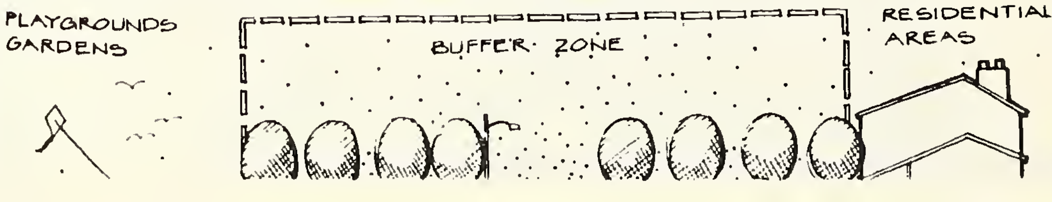


FIGURE 3.5
The problem: lead is concentrated in air, soil, and plants along streets, a function of traffic speed, volume, and distance from roadway. Here, along a street averaging 24,000 vehicles per day, under calm conditions, lead in the air above the street is sixteen times the "normal" urban atmospheric lead content, falling off to eight times normal fifty meters (164 feet) away.

of the road (see figure 3.5).[8] In the area immediately adjacent to the road, the most highly polluted, the lead content of the air is sixteen times the "normal" urban atmospheric lead content. At fifty meters (164 feet), lead in the air is only eight times normal.[9] Since the concentration of pollutants falls off sharply at ten meters (33 feet) and continues to decline with increasing distance from the roadway, border areas of at least ten meters (33 feet), should separate the road edge from the sidewalk. Rows of trees, planted in the buffer zone, will enhance the setback by filtering fumes and dust and reducing street noise (see figure 3.6). Frankfurt, Germany, one of a number of

FIGURE 3.6
The solution: a multifaceted approach to limit air pollution exposure along streets: traffic regulations to reduce the production of lead and other pollutants; landscaping to capture particulates; and setbacks to minimize exposure. Traffic volume determines size of setback.



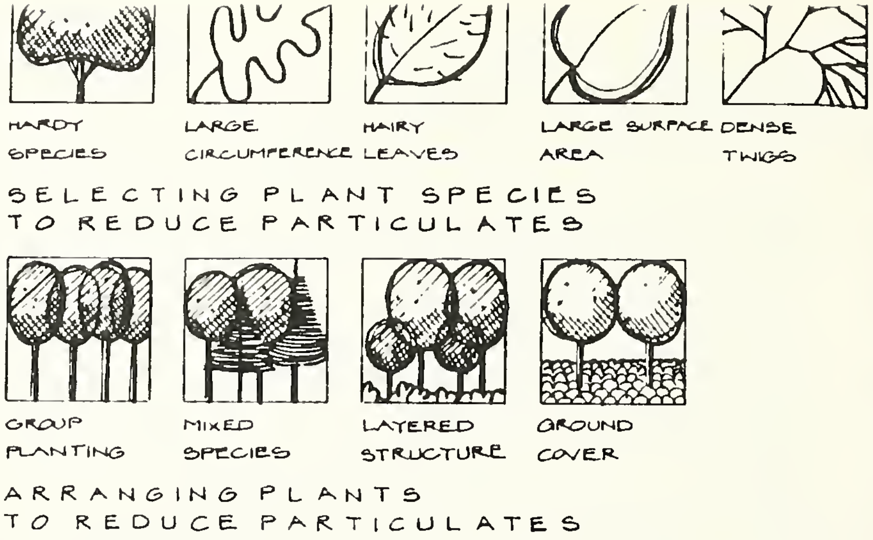


*FIGURE 3.7*
Using plants to reduce particulate air pollution. Certain types and arrangements of plants create effective air filters.

European cities that have long recognized the value of street trees for this purpose, plants four rows of trees along major boulevards. Wiesbaden recommends two rows of trees along each side of major city streets.[10]

Trees remove some of the carbon monoxide and particulates emitted by vehicular traffic, a function enhanced by several factors (see figure 3.7). Because the removal rate of gaseous pollutants is dependent upon the tree's vigor, species should be selected for their hardiness under city conditions. Trees will filter particulates most effectively if they have dense branches, rough bark and twigs, and hairy leaves with a high ratio of surface to volume.[11] Since soil is also an effective sink for pollutants, removal of pollutants is enhanced when trees are planted in soil covered with leaves and plants, rather than pavement.

Schools, houses, sitting areas, and playgrounds should be set back beyond the polluted zone, more than 150 feet from the street edge whenever possible,[12] and separated from the roadway by belts of trees, which should be spaced far enough apart to permit the free movement of air under their canopies. The setback of homes, hospitals, offices, and stores from arterial streets will have the additional benefit of enhancing ventilation and preventing the formation of stagnant air pockets. The height of buildings in relation to the width

ing in order to dissipate local inversions at street level and to allow the penetration of ventilating breezes to disperse and dilute contaminants. Cities should study the effects of varying wind directions and speeds upon the shape and size of the polluted zones. (Wind tunnel tests are currently the most reliable way to predict air movement at this scale, but computer models that predict the diffusion of air pollution in urban street canyons may ease this task in the future.)

Although the location and width of expressways are frequently influenced by existing urban conditions, there is more flexibility for selecting a new highway's location and making improvements in an existing right-of-way than there is in enlarging existing arterials. New highways should be located in areas with favorable ventilation and separated from places where people live and play. The right-of-way should include the entire area of the polluted zone, on both sides of the road. It should be planted with trees and shrubs to filter pollutants. Bicycle and jogging trails and vegetable gardens are not suitable uses for expressway rights-of-way.

Collector streets, in contrast to both arterials and local streets, are neither entirely for traffic nor entirely for people. They distribute traffic throughout the city and are heavily traveled by cars and trucks, serving as many as 15,000 vehicles per day, yet they are also the place where many people shop and work. The polluted zone of collector streets is likely to be smaller than that of arterials, but the same design principles apply. Sidewalks should be wide and separated from the roadway by a large border area planted with trees whenever possible. Small parks and plazas located along collectors should be set back and separated from the street by rows of trees.

Not all cities, especially older ones, can comply with standards for new street design. The intricate maze of narrow medieval streets characteristic of European cities like London, Copenhagen, and Amsterdam, the street canyons hemmed in by towering buildings epitomized by New York City, and the expansive streets of midwestern cities like Dayton—each pattern engenders its own problems and requires its own solutions. Local streets may be redesigned and reconstructed with relatively little impact on the rest of the city, but strategies for improving health and comfort on major streets are often at odds with the need to promote access and efficiency of movement. The woonerf concept is appropriate only where most cars have a local destination and traffic is below 300 cars per hour.[13] Any technique that reduces traffic speed on major streets will only exacerbate air pollution.

one another. Limiting automobile traffic or banning it entirely, especially in narrow, poorly ventilated streets, may be the only solution to an intolerable problem.

Madison Avenue, in New York City, is not narrow by standards of most cities, but the height of the buildings that line it produces a deep canyon. Madison Avenue runs north to south on Manhattan Island and the sun often does not reach street level until midday. The result is frequent morning inversions that trap the exhaust from rush hour traffic at street level (see figure 2.1). Park Avenue, a much wider street one block away, is much better ventilated. The morning sun probably prevents inversions in the many east-west streets which cross Madison Avenue. Design palliatives will make no dent in Madison Avenue's air pollution, and further construction of tall buildings will certainly aggravate it. The only alternative, in this case, is to ban or limit traffic where skyscrapers crowd the street.

In Europe there are many precedents for eliminating cars, trucks, and buses from city streets. Stockholm, Rotterdam, Bologna, and Vienna have all banned traffic from various parts of the downtown, as have some American cities. Strφjet (Danish for "stroll"), a connected system of narrow streets in central Copenhagen, has been dedicated to pedestrians since 1962. Today there are more than 2,000 stores along Strφjet, among them the city's most expensive department stores and boutiques, as well as some of its most popular restaurants and cafes. Strφjet appeals to tourists and natives alike. People—strolling, strutting, sunning, sitting, watching, and eating—have replaced the car on the street; delivery trucks have access in the early morning only or from streets at the side or the rear.

## *Creating More Comfortable Parks and Plazas*

Public squares have always been in fashion. They were at the heart of ancient Greek and Roman cities, medieval towns, and later provincial villages, as well as the modern metropolis. They are places to see and be seen, to shop and conduct business, to promenade and politic. The best plazas are pleasant places most of the year, moderating the heat of midsummer and warming the chill of early spring and late fall. Such places are rare and prized.

Shady havens are comfortable places to sit. Paley Park in New York City (figures 3.8 and 3.9) is such a haven off busy, noisy, mid-

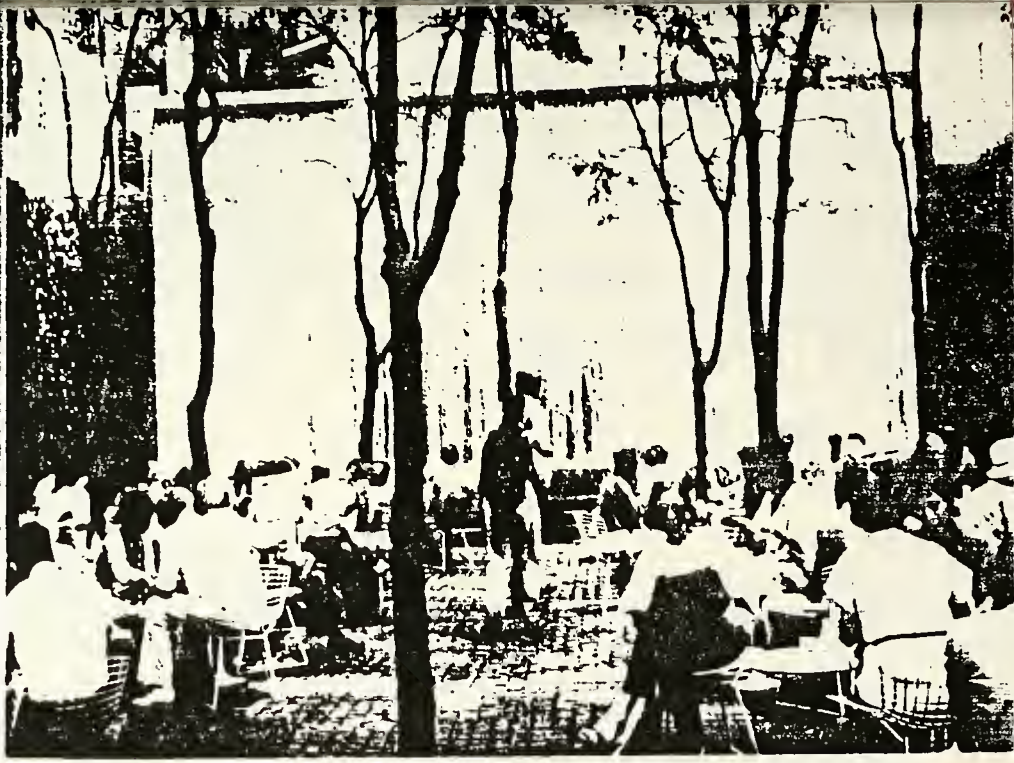
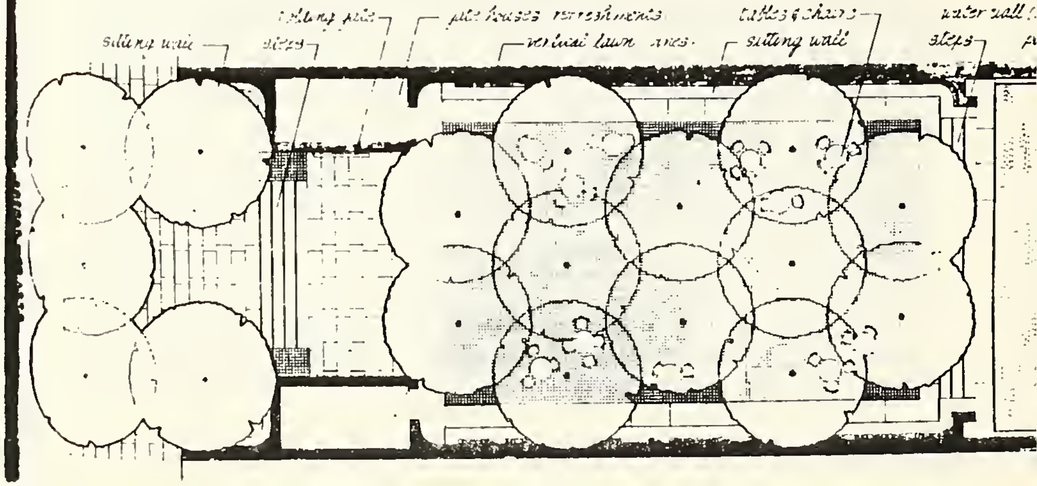


*FIGURE 3.8*
Paley Park, one of the most intensively used parks in New York City, a comfortable, shady haven.

*FIGURE 3.9*
Plan of Paley Park, showing the simplicity with which its climatic effect is achieved: a waterfall, vine-covered walls, and a canopy of trees.



town East 53rd Street. On a hot, humid, airless summer day, this small park is refreshingly cool. At lunchtime it is crowded with shoppers and office workers. Paley Park is quite small and intimate—the size of one building lot. Adjacent buildings tower over the park, yet it does not feel cramped. A dozen honey locusts, their trunks slim columns, form a lacy roof over the park. The leaves admit a filtered, dappled sunlight. A denser tree, like the Norway maple, would have cast a dark shade and made the park an oppressive hole. A waterfall is the endwall of the park. Its soothing, rushing sound masks the street noise outside. Water splashes onto the surrounding pavement and cools the air as it evaporates. On a hot day, the seats closest to the water are claimed first. The two sidewalls are covered with ivy, which blocks both reflected sunlight from the walls and the radiant heat they might otherwise emit outward. Chairs and tables are movable, locked in at night for security. The distance between chairs can be adjusted to accommodate groups, couples, or solitary visitors. Chairs can be moved close to the waterfall or further away and in or out of the sun, depending on whether the day is hot or cool. Paley Park is often copied. It is an excellent example of how a dramatic change in urban microclimate can be accomplished in a very small space.

A sunpocket, a protected place that feels 10 degrees to 40 degrees Fahrenheit warmer than a more exposed spot nearby, can extend the use of an outdoor space by two to three months in a cool climate. It is a paved, south-facing corner, protected from the wind; its walls catch the sunlight and reflect it back into the space. Its pavement, preferably dark, absorbs and reradiates heat from the sun and heat reflected off surrounding walls. A pedestrian can sit quite comfortably in a New York City sunpocket in April or November without a coat. While a thermometer in the wind and sun reads 52°F, a thermometer in a sunpocket may read 80°F or 90°F.[14] Sunpockets have a desertlike microclimate—warm and dry while the sun is out, cold on a winter night after sunset—so plants chosen for such a place must be able to tolerate these extremes.

Shady havens, like Paley Park, and sunpockets are based upon the same principles of heat exchange. Shady havens prevent heat gain and encourage heat loss by blocking direct sunlight, by preventing the absorption of heat in surrounding surfaces and its subsequent reradiation, and by encouraging evaporation and the penetration of breezes. Sunpockets enhance heat gain and retard heat loss by cap-

of location, form, and building materials contributes to the success of a shady haven or sunpocket. A southwest orientation is optimal for sunpockets. Whenever possible, shady havens should be located to capture sea breezes, hillside breezes, and prevailing summer breezes. Selection of the right materials is fundamental. Shallow, porous, heterogeneous pavement (brick in sand) absorbs heat more slowly and stores less than a deep, dense, homogeneous pavement (concrete). Light, smooth pavement (concrete or marble) absorbs less and reflects more radiation than dark, rough pavement (asphalt). Wet surfaces (pavement, roofs, ponds) produce a cooling effect as water evaporates. Trees cool not by shade alone. Water, pumped from the ground, evaporates from their leaf surface so long as water in the ground is plentiful.

Ideally, shady havens and sunpockets should be located throughout the city, integrated into plazas and parks. They can be simple and inexpensive. Paley Park is between Fifth Avenue and Madison Avenue in a fashionable section of Manhattan and has a lavish maintenance budget. Many similar parks built since, such as Waterfall Garden in Seattle, Washington, and Greenacre Park in New York City, were also costly to build and maintain, but such expense is not essential. A similar microclimate effect could be achieved in a vacant lot on a much smaller budget. City "weed" trees, like ailanthus, provide shade within a few years after planting and need not be purchased. Vines on walls and low plants on the ground reduce glare and radiant heat. A simple sprinkler—a cheap alternative to pools and fountains—increases both physiological and psychological comfort, even in a humid climate.

## *Designing a Cleaner, More Comfortable, and Energy-Efficient City*

To be most effective, the design of a single street, park, or plaza should be part of a comprehensive strategy to improve air quality, conserve energy, and improve comfort throughout the city. Problems at one street corner may find their cause elsewhere, and solutions to air quality may increase discomfort.

Take the example of downtown Dayton, Ohio, where winds are a

Had icy sidewalks in winter and such forays become perilous.

This problem was studied by graduate students in landscape architecture at Harvard University. They had spent months studying climate and its application to urban design, and they marshaled all the new tools that they had acquired to solve this problem of a windy street corner. They proposed different configurations of trees, awnings, and walls, then tested their designs in a wind tunnel. The effect on wind speeds was insignificant. The steel wool mounted on pins used for trees on the model was destroyed by the force of the wind. The students lamented that the severe downdrafts had not been anticipated before the apartment complex was built, for then the entry and the building could have been redesigned. Beyond destroying the building and reconstructing it there seemed to be no satisfactory resolution to the problem. This conclusion is where most such studies end. Fortunately, this study was an academic exercise, and the elderly housing project but one short case study, part of an overall investigation of climate and air quality in the city as a whole. The students went on to prepare a master street-tree plan for the entire downtown and in the course of that work found an answer to the problem of the elderly housing complex.

The answer lay in looking at the city as a whole. Dayton's downtown is surrounded on three sides by open land which presents little friction to the wind. Parking lots, institutional grounds, a highway, and a river ring the city. Winter winds from the northwest sweep unbroken across an expanse of parking lot, then hit tall buildings like the elderly apartment complex with full force, sweeping down and around them. The link between windswept parking lots at the periphery of downtown and turbulence around tall buildings in the center was clearly demonstrated in wind-tunnel tests where the effect of winds of differing force and direction was simulated by blowing air over a scale model of the entire downtown (figure 3.10). When trees were added to parking lots on the northwest edge, the wind problems around the entry to the apartment complex were reduced to the point where awnings and trees around the building could solve the remaining problem. Once recognized, the solution seems simple. But the method for identifying the solution was revolutionary.

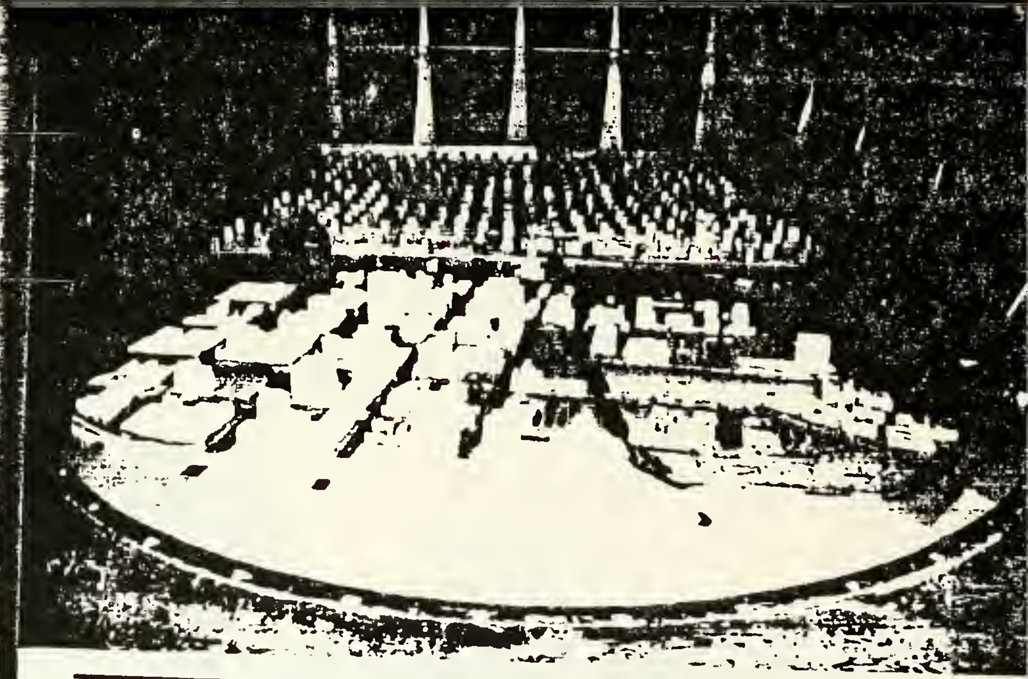


*FIGURE 3.10*
Model of downtown Dayton in wind tunnel used to predict wind problems and test solutions. Studies of the entire city rather than a single building reveal that small changes can have unexpected and far-reaching consequences. Air blowing through spires and across grid simulates wind behavior as it approaches Dayton over the surrounding suburbs.

This was the first time designers had studied a scale model of an entire downtown in a wind tunnel for the sole purpose of developing a comprehensive plan that would resolve ground-level wind problems. Wind tunnel studies are rarely undertaken before buildings are designed and constructed. They are most often conducted when a disastrous wind problem becomes apparent after construction—when doors won't open, when windows pop out, or when pedestrians are knocked to the ground. A scale model of Prudential Center near Boston's Copley Square, as well as of places in other parts of the country, decorate the walls of M.I.T.'s wind tunnel, unspoken testament to the commercial, aesthetic, or political disasters they represent. The Dayton model was six feet across; small enough to see the city as a whole, but large enough to depict the detail of sidewalks and streets, parks and plazas. One inch on the model was equivalent to fifty feet on the ground. All the buildings of Dayton's downtown were represented in wood, and had been made by two Dayton park department employees in the city's shop. An assistant to Dayton's city manager transported these model buildings to Cambridge in suitcases. Students at the Harvard Graduate School of Design mounted the buildings on a round base complete with streets, highways, river, and parks, and even individual trees represented by steel wool on pins. They then used the model to study the effect of different wind conditions and solar orientations on comfort and air quality in downtown Dayton.

Like many cities, Dayton has wide streets and much open land near downtown. Since not all six lanes of downtown streets were required to accommodate traffic, students proposed that median strips and sidewalks be widened and planted with trees. The configuration of street tree planting and the species of trees recommended varied from street to street, reflecting the street's orientation to sun and wind, the width and height of the street canyon, and its importance to traffic and commerce. Students determined the location of trees by reference to maps of sun and wind problems which they had drawn up using the model.

Because parking spaces abounded, parking revenues would not be decreased by adding trees in the lots. There were four different considerations in designing the parking lot plantings: to reduce the force of the winds before they hit the city center; to be equally effective in reducing winds from different directions; to provide shade to the surface of the parking lot; and to avoid trapping pollutants from automobile emissions under the tree canopy. The resulting design was a grid of trees evenly spaced along the periphery and within the parking lot. Planting the trees in a grid rather than in parallel rows would make the trees effective in reducing winds from many directions. The trees were spaced close enough to provide shade but far enough apart to permit ventilation. The design for the parking lot for the southwest varied slightly from that for parking lots to the northwest. The prevailing winds in the summer come from the southwest, so providing shade to the parking lot surface was more important than slowing the wind. The trees in the parking lot to the northwest were spaced further apart, creating a rougher surface and thereby slowing the wind more effectively.

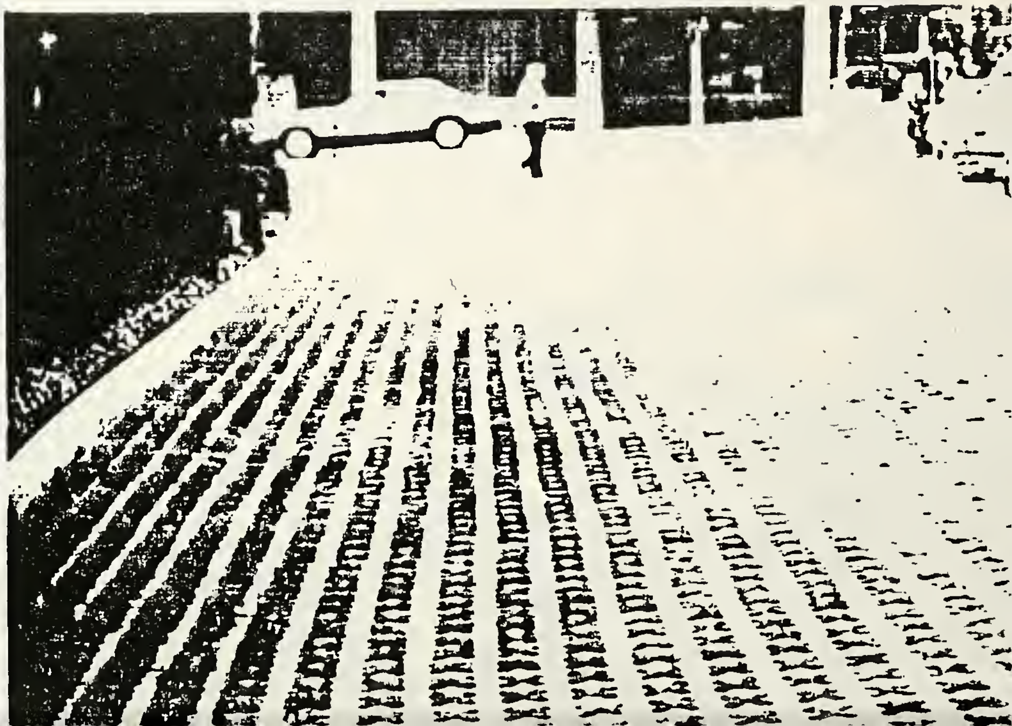
The students presented the results of their semester's work, a master plan for street tree planting in downtown Dayton, to the Downtown Dayton Association, a group of local merchants, businessmen, and interested citizens.[15] They estimated that the cost of installation and maintenance of the trees would be no more than what the merchants currently paid for their streetlighting, an assessment based on the length of street frontage.

The student's plan is only one part of Dayton's climate project. Through an ingenious marshaling of federal funds, grants from private foundations, the expertise of students and faculty at a number of colleges throughout the United States, and the donation of time from many individual city residents, Dayton has put together an impressive constellation of urban climate projects. In 1980 the United States Forest Service lent Dayton a climatologist who studied the city's climate and air quality and assessed its needs. When more data were needed about temperatures in the city, the city manager's office, through appeals on television, organized an army of volunteers throughout the city to record temperatures on particular days at specific times. The resulting information permitted the climatologist to draw conclusions about Dayton's temperature regime with some confidence.

In 1981 the City of Dayton constructed an experimental parking lot composed of turf blocks (a tessellated pavement of grass and concrete—see figure 3.11) rather than the conventional asphalt. The

*FIGURE 3.11*

Turf-block parking lot. Grass grows in the holes of precast concrete blocks, kept short by traffic. This material absorbs far less heat than asphalt.



turf-block parking lot absorbs and reradiates less heat to adjacent building walls and sidewalks; air temperatures on sunny afternoons over the turf-block parking lot are routinely 4 degrees Fahrenheit cooler than over a nearby asphalt parking lot.[16]

The city has recently embarked upon an experimental highway planting program, and is permitting natural vegetation to regenerate along selected segments of the highways which ring the city. Dayton hopes to filter pollution, reduce highway noise, reduce wind velocities before they reach the downtown, and to provide an attractive gateway into the city. It also hopes to cut maintenance costs, as mowing will not longer be necessary.

In 1980 Dayton launched a newsletter, *International Dayton Line,* to inform other cities about its urban climate project. The newsletter now reaches more than 700 readers, and it has become a clearinghouse for information about cities which are attempting to apply innovative approaches to climate, air quality, and city design. Other U.S. cities like Cincinnati, Buffalo, and Lafayette, Indiana, have been inspired by Dayton's example and have initiated similar programs.

Dayton's climate project was launched by a former city manager after he saw a film documenting the achievement of Stuttgart, West Germany, an industrial city of 630,000. Like many inland valley cities, Stuttgart is plagued by extended periods of weak winds and frequent persistent inversions (247 days per year) which result in dangerous concentrations of air pollutants.[17] For more than three decades, climatologists, city planners, landscape architects, and architects have worked together to implement a bold plan to alleviate the city's air quality problem. The planners of Stuttgart have engineered air circulation on an unprecedented scale. They have directed and diverted air flow through the city and guided the location of industries, highways, and residential districts to benefit air quality and climate. They have implemented a comprehensive plan and coordinated many smaller projects throughout the city.

Having plotted the patterns of air circulation through and around Stuttgart (see figure 3.12), climatologists continue to survey levels of air pollution and dust to pinpoint the most critical areas. Initially, they released smoke to trace the flow of air into the city. More sophisticated techniques, including the use of infrared aerial photographs, are now used to provide the same information. Studies identified undeveloped hillsides above the city as a major source of clean, cool air which flows nightly down ravines into the city. At the time their crucial role in city ventilation was discovered, the wooded hillsides were rapidly being converted to residential sub-

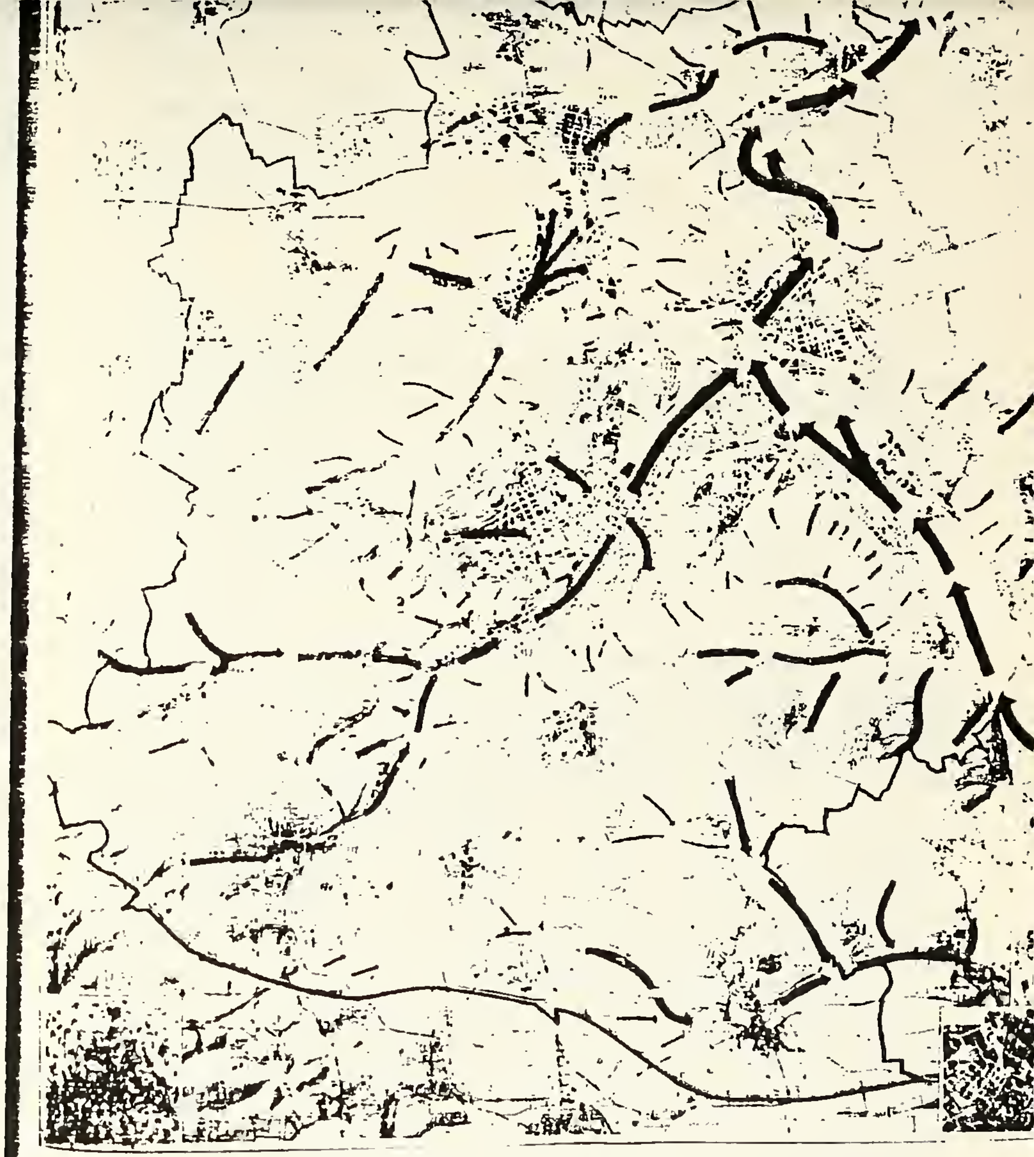


FIGURE 3.12
Air-flow patterns in Stuttgart, Germany. At night, under calm conditions, cool, clean air flows down the hillsides into the city, pushing out hot, dirty air in the downtown.

restricted the development of those hillsides and incorporated them into a radial open space system extending from the rural outskirts of the city to its center. As hot, polluted air rises over the downtown, cool, fresh air is pulled in along the open space corridors to replace building and effective only when the velocity of regional winds is less than two meters per second. During the frequent, lengthy periods of low regional winds, this hill-to-valley air movement provides the only ventilation in downtown Stuttgart. It cools the city at night, a time when the city would otherwise be much warmer than the suburbs. Land use within "fresh air channels" is therefore strictly regulated by the city. One hundred meters is the preferred minimum width for these air flow channels, which are planted with grass and trees.

Emission of pollutants in Stuttgart was attacked on several fronts. Inversions normally affect a relatively shallow layer of air over the city. If the chimney stacks of industries, public incinerators, and power plants are tall enough to pierce the top of the inversion layer, their emissions will escape the volume of air trapped near the ground. Municipal incinerators and power plants were consolidated and moved downwind from the city, and tall smoke stacks, 160 to 180 meters high, were installed.[18] Many industries have since followed the city's example. Traffic was banned from poorly ventilated downtown streets. The burning of oil and coal was prohibited in sections of the city where wind velocities are insufficient to flush the air. In these areas, only natural gas is used for cooking; the city provides water warmed by municipal incinerators to heat homes. Together, these efforts have substantially decreased air pollution. Stuttgart has also taken measures to provide more comfortable outdoor spaces and to reduce summer air conditioning costs. Meteorologists and planners on the staff of the Chemical Investigations Office review plans of new buildings to determine their impact on climate and air quality at street level and recommend revisions in building design to improve ventilation and microclimate. The agency recently suggested the widening of several streets in the downtown area to improve air circulation. The Theodorheusstrasse was widened, and the space gained was planted with large, thirty-five-year-old sycamores.[19] Roof gardens and "wet roofs" (a flat roof with a few inches of ponded water) have been introduced to reduce the heat absorbed by buildings. Parking lots have been converted from asphalt to turf-blocks to decrease the heat absorbed. The city built shady, landscaped parks, linked to air flow channels wherever possible, to provide pleasant oases, to cool adjacent neighborhoods, and to filter dust from the air. Such efforts have perceptibly improved the microclimate in downtown Stuttgart.

The Stuttgart solution is most applicable to cities with frequent, graphic and climatic features have been most successful in its application. By harnessing natural patterns of air flow to ventilate the city and by regulating polluting activities, Stuttgart has transformed itself from a city with poor air quality into a model for the world.

The city of Davis, California, has pioneered multifaceted legislation for energy conservation, including a new building code, ordinances that encourage the use of solar energy systems, and the development of alternative transport to the private automobile. The city decided to concentrate on building construction and transportation, since a survey of residents conducted in the early 1970s had demonstrated that automobiles represented 50 percent of all energy consumption, and space heating and cooling an additional 25 percent. The new building code, developed with the assistance of researchers at the University of California, Davis, regulates both the siting and design of new buildings, including solar orientation, insulation, amount of window area, exterior roof and wall colors, and overhang shading. Prior to the building code, most homes were built with air conditioning. With improved design, residents now find air conditioning unnecessary.

Davis has explored many ways of reducing automobile use. The city council decided to develop a system of bikeways in 1968, and since that time has introduced convenient, low-cost public transportation. By encouraging cottage industry, the city also hopes to reduce commuting.

The Davis experiment has proved highly successful. A small city of 33,000 people, Davis was able to explore, implement, and test techniques for energy conservation which may now be adapted to larger cities. Since energy conservation decreases both waste heat and pollutants, improved climatic comfort—a result of careful siting and housing design—and improved air quality—a result of decreased automobile traffic—are important by-products of the Davis plan.

## A Plan for Every City

Both the Stuttgart plan and Paley Park affect the microclimate and air quality at street level. Stuttgart's is a grand scheme; it affects an entire city and captures the imagination. Paley Park is a modest project; it improves the microclimate of one small space, but delights to the special character of other places.

An understanding of the climatic and air pollution patterns of the city as a whole should underlie every project, whether ambitious or modest. A city's regional climate, topographic setting, pollution sources, and urban form determine its most critical problems of climate and air quality. Specific phenomena, their spatial patterns, and relative importance vary from city to city. Are long, cold winters a problem, or hot, dry summers? Too much wind or too little? Susceptibility to regional or local inversions? Large, industrial polluters upwind of the city, or the accumulation of automobile exhaust within the city? Identifying the major sources of air pollution within the city, the dispersion patterns of pollutants, and areas like valley bottoms and narrow street canyons that are prone to inversions will aid in singling out the most severely contaminated places. Plotting daily temperature variations within the city, including "hot spots" and "cool spots" will identify some of the city's most uncomfortable places and also may help to predict thermal breezes. Knowing the pattern of air movement around and within the city will permit its use as a resource to help disperse pollutants and enhance comfort and energy conservation. The daily and seasonal variation of air movement, including the direction, speed, and frequency of regional winds, as well as of valley, shore, and other thermally induced breezes, is potentially of great importance, particularly during episodes of stagnant weather.

Comprehensive strategies to improve air quality, enhance comfort, and conserve energy for heating and air conditioning through urban form should:

- address the city's most critical climatic and air pollution problems, with particular attention directed to the improvement of conditions in the most severely contaminated and the most uncomfortable areas
- investigate alternative modes of transportation and sources of energy that would curtail air pollution and explore settlement patterns that would facilitate their implementation
- encourage new industry, public utilities, and highways to locate in well-ventilated areas where they will not contaminate residential and commercial neighborhoods under prevailing wind or inversion conditions
- locate parks and other landscaped open space to preserve fresh air flow into the city, to enhance ventilation, and to dilute and remove pollutants
- exploit the potential of large-scale tree planting within the city to offset the heat island effect in summertime and to mitigate wind problems.

Every new building, street, highway, and park within the city should be designed to avoid detrimental alterations to the climate

improve them. Every project, however modest, should:

- address the relationship of its location to the critical climate and air quality problems of the city as a whole as well to those of the site and its immediate neighborhood
- exploit those aspects of the citywide and local climate that can be used to resolve the above problems
- locate new playgrounds, bicycle paths, jogging or walking trails, and sitting areas away from arterial streets, highways, and other air pollution sources
- maintain a setback from major streets and highways based upon traffic volume and prevailing wind directions
- exploit opportunities for passive energy conservation in the design and siting of buildings and parks
- orient buildings, streets, and parks to funnel desired breezes and block unwanted winds
- utilize building and landscape materials to create a desirable microclimate—to capture or reduce heat absorption and to increase or decrease wind velocity.

Every city must weigh the consequences of ignoring climatic concerns and the potential benefits of a comfortable city with cleaner air against the costs of implementing such strategies. To change the climate or even the ventilation pattern within an entire city is an overwhelming and ambitious undertaking. It has been done, but it is likely to be attempted only in cities where air pollution is a public health problem of enormous and widely recognized significance, as in Stuttgart. The potential impact and opportunity is greatest in new or fast-growing cities with a predictable or severe air pollution problem, like Tucson, Arizona, or Denver, Colorado. Unchecked development in Tucson and Denver will have disastrous consequences for health. Sorely needed are carefully laid plans for future urban growth including the search for alternatives to the private automobile as well as the careful siting of industry and highways in relation to residential districts and to topographic features favoring pollution dispersion.

For older cities, or those with less severe problems, it is more feasible to change the city's climate piecemeal, as parts of the city are altered or rebuilt. Here, it is more practical to focus on the most critical areas in the city: the most uncomfortable and most contaminated places and the most important public spaces or those used by the most people. These can be redesigned to make them healthier, more comfortable in summer and winter, and to extend their use earlier into spring and later into fall. The knowledge and technology exist; the costs for incremental improvement, when combined with new construction, are small. The social and economic costs of disregard are great.

# THE UTILIZATION OF DAYLIGHTING AS AN URBAN DESIGN STRATEGY

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## ABSTRACT

The potential of daylighting in urban design practices will be developed in three parts. In the initial part, data will be presented in order to assess past practices. Of special interest will be the daylighting techniques that have been used in early U.S. urban design practices. In the next part, a daylighting methodology will be presented which has recently been proposed for incorporation into New York City urban design practices. In the final part, this proposed methodology will be evaluated, the outcome of which will suggest that daylighting can be a significant urban design strategy.

## 1. INTRODUCTION

Assuring adequate light and air to the urban environment was a prime motivation in enacting many early zoning ordinances. However, with improvements in building technology, the quality of what was deemed deficient in earlier urban environments was thought to have been improved. Thus, over the years, daylighting as an urban design strategy came to be neglected. Today, we are discovering that in addition to its qualitative benefits, daylighting is a promising energy conservation strategy that reduces artificial lighting which is often the single largest energy consumer in commercial buildings. Although substantial savings in both electrical energy and peak power demand can be expected, it is not obvious that these savings can be achieved under existing urban design practices, which give little incentive to provide daylighting to the urban environment.

## 2. HISTORICAL PRECEDENTS

The public regulation of daylighting is not a modern invention; we know that the ancient Greeks and Romans mandated minimum lighting standards for their cities. Another early attempt to insure the availability of daylighting was the British Law of Ancient Lights, which dates back to 1189, and was embodied into statute law in "The Prescription Act of 1832." Under this act, if a window in a building enjoyed uninterrupted access to daylight for a twenty year period, right to that access became permanent. Any construction adjacent to a building protected by Ancient Lights was prohibited from encroaching upon that right. Unfortunately the U.S. had no such law, and it was not until the turn of the century that daylighting problems in our cities began to attract attention.

In 1912, a Boston architect named William Atkinson, developed a technique for quantifying how changes in orientation, shape and building height affected light to the street.[1] His findings led him to hold strong views on the need for legislation to control the height of buildings. Unlike the simple maximum height limits that many were advocating, Atkinson proposed to limit building height by means of an angle drawn from the opposite side of the street through a point on the building one and one-quarter times the street width (see Figure 1).

In 1913, shortly after the publication of Atkinson's work, the first attempt to develop daylighting standards for the U.S. was made with the establishment of the New York Heights of Building Commission. The commission studied various legislative controls adopted in other countries, solicited the opinions of interested parties to the idea of controls, and identified existing physical features of the city. In 1915, the commission recommended that New York City should be zoned on the German system, according to existing uses and building types and that maximum building heights should

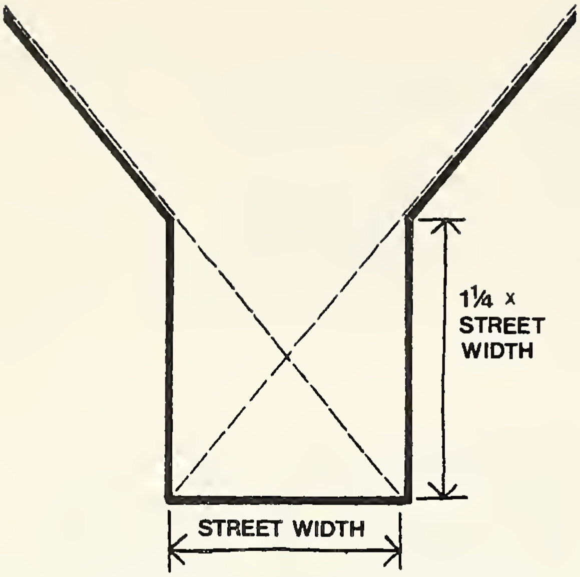

Fig. 1 Atkinson's proposal for limiting building height.

be established for each district.[2] Many of these recommendations soon found their way into legislation via the 1916 Zoning Ordinance.

### 2.1 1916 Zoning Ordinance

New York City's 1916 Zoning Ordinance was the first comprehensive municipal attempt to legally guide and control the physical form and function of a city.[3] The ordinance guaranteed minimum street-level standards of light and air by incorporating two innovative approaches: the street wall concept and the sky-exposure plane (see Figure 2). The street wall concept dictated that the height of the building wall closest to the street was to be a product of the street width times a certain multiple which varied dependent on locale. The city was broken into five "height districts" which attempted to recognize perceived utility, neighborhood character, and the need for pedestrain amenity (see Figure 3). For example, Fifth Avenue with its low scale building and carriage trade retail was designated a lower height district than surrounding streets and avenues. The sky-exposure plane described the amount of sky that could be seen from the center of the street, and was a direct result of the street wall height. The lower the height district, the greater the sky-exposure and the more light that reached the street.

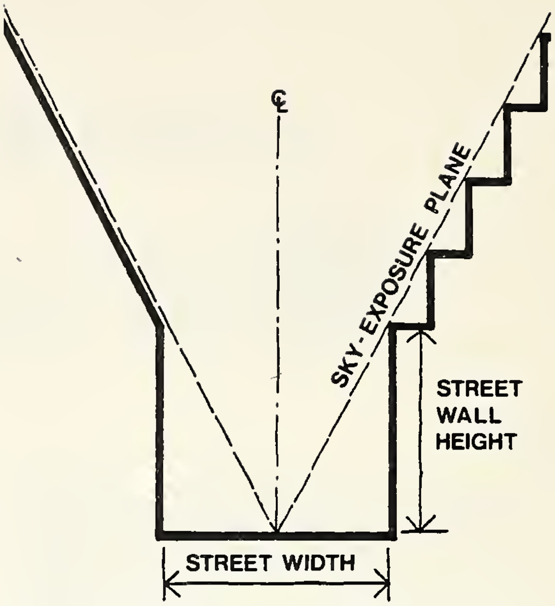

Fig. 2 New York's 1916, street wall and sky-exposure plane concept.

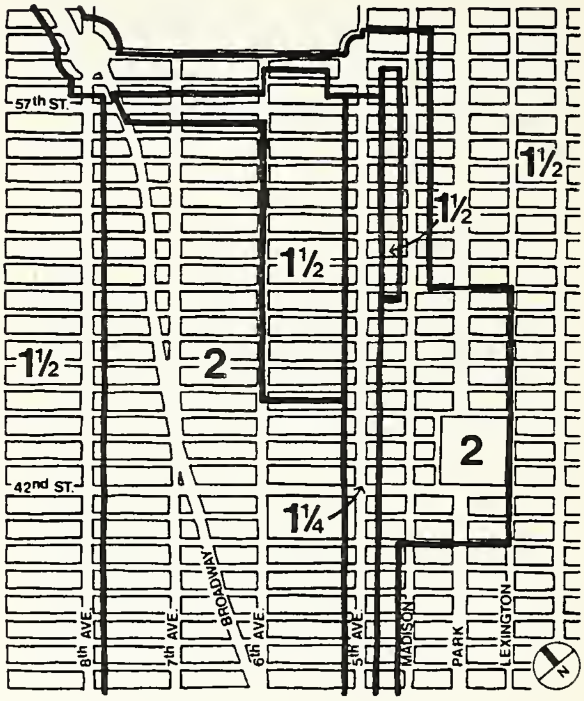

Fig. 3 New York's 1916, height district map.

These concepts had major architectural ramifications. The street wall regulation limited the allowable bulk of a building's base, while total building bulk was limited by the sky-exposure plane regulation and a 25% area limit on tower coverage. Buildings rose from the street to their allowable street wall height and then began a series of set backs in order to remain within the sky-exposure plane. When the floor area was no larger than 25% of the site a tower of unlimited height was allowed. The fact that the "wedding cake" building became characteristic of this ordinance says more about the limitations of the design community than the ordinance itself, because such diverse buildings as the Empire State, RCA and Seagram Buildings were also products of the 1916 ordinance.

Over the years, numerous amendments were made to the original ordinance although the basic framework remained intact. However, by the late 1940's, many felt that the tenets behind the 1916 regulation were no longer appropriate. Thus, in 1950 the City Planning Commission began the process of revising the city's zoning regulations in a report entitled Plan for Rezoning the City of New York.[4]

## 2.2 1961 Zoning Resolution

While not officially adopted, the majority of the recommendations of the 1950 report found their way into the 1961 Zoning Resolution.[5] This regulation continued the precriptive format of the preceding ordinance, but was extremely different in content. Whereas the earlier regulations tended to produce street related buildings and assumed public development of concentrated open space, the new regulation sought openness at grade on each site in the form of privately constructed amenities such as plazas.

The transition from more contextual buildings to a series of free-standing structures (either towers, slabs, or tower and base) had enormous physical ramifications on the city. Unlike the 1916 ordinance, where the building size was controlled by technology, site and market conditions, building size was now based on the Floor-Area Ratio (FAR), a number that determines the building's floor area in relation to its site area. Although street wall heights were lowered, more building bulk was allowed in the towers, which could now occupy 40% of the site. The As-of-Right zoning system awarded developers 20% more FAR in return for the provision of an outdoor amenity - a plaza occupying at least one third of the site - which effectively guaranteed daylighting standards equivalent to the 1916 resolution. Although daylighting was equivalent, the 1961 resolution created a building type that did not conform to the existing character of the city, but rather to an envisioned "City of the Future." The massive discontinuities between old and new were apparently perceived as a minor inconvenience that would have to be endured until the vision reached fruition. However, as the vision began to develop in locations such as along Sixth Avenue, reaction set in. The grinding uniformity of these buildings and excesses of underused or poorly located plazas threatened the urbanity of New York.

The city responded to this dilemma by expanding the Special Permits Section of the original resolution, to include additional FAR for interior amenities (arcades and midblock passages), and allowed for modification of height and setback regulations. Such incentives were envisioned as a means to encourage buildings to resume their tradition role of defining the public space of the street. However, the discretionary review process which came with the incentive approach was inherently nonobjective and frequently disregarded the traditional role of zoning to provide light and air to the street. Many of the special permit buildings which rise sheer from the street have no more bulk than earlier buildings, but through their bulk location have reduced daylight and street space to pre-1916 levels. Joana Battaglia, head of Community Board 6, eloquently expresses the frustration that many New Yorkers currently feel, "we are having unwanted amenities foisted on us at the expense of the best amenities of all - light and air."

## 3. 1980 MIDTOWN DEVELOPMENT PROJECT

In the 1980 proposed zoning revision for Midtown Manhattan,[6] the perception of building height and bulk, and light to the street are once more key concerns. Many of the problems currently experienced in Midtown are a result of the abstract manner in which the 1961 regulation and the special permit process handled these issues. By contrast, the 1980 proposal relies on a performance approach which evaluates the urban environment directly in relation to the way a pedestrian perceives that environment.

The performance approach attempts to regulate development by requiring that a building maintain the context of its surroundings - as perceived by a pedestrian in the street. Perception is a function of a building's mass, space, and light, which for zoning purposes translates into street wall height and length, as well as its daylighting.

In order to receive zoning approval under the performance approach, a proposed building must score 85 points out of a possible 100 on a four part performance test. The first two tests, street wall height and length - worth

15 and 25 points respectively - measure the building's adherence to the physical character of its surroundings. An optional test for reflectivity, worth 5 points, rewards a developer for the use of light-colored exterior materials. The remaining test, for daylighting, is the crucial test and is worth 60 points, with 40 as a mandatory minimum.

The daylighting test uses a specially developed daylight evaluation diagram which is a modified version of the Waldram diagram to measure the amount of daylight a building allows to the street (see Figure 4). The diagram - which resembles the fisheye distortion in photography - creates a two-dimensional representation of a building's three-dimensional reality. This diagram includes a network of daylighting blocks which signify the varying qualities of daylight that comes over the top and around the sides of a building. The unobstructed blocks are multiplied by their assigned value and then totalled, resulting in a daylight equivalency score. Daylight equivalency is performed twice for each street on which a building borders, evaluating the perceived presence of the proposed structure from a point 250 feet from the far property line.

In the process of developing the performance approach, a number of existing buildings were evaluated for daylighting equivalency. Figure 5 shows one of the diagrams that was used in an evaluation of the Citicorp Center. The shaded area represents the building's bulk, while the light areas represent unobstructed daylight. From this particular orientation the building allows significant amount of daylight to reach the street. Although the Citicorp Center passed solely on its daylighting performance, it accumulated additional points on the reflectivity test. Its light colored exterior reflects daylight into nearby streets and open spaces, enhancing the perceived quality of these environments. The Citicorp Center, however, was designed with some notion of pedestrian amenity and open street-level spaces. Other recent projects such as the AT&T Building and the IBM Building, both of which are still under construction, aren't nearly as successful in this regard; both failed the proposed performance tests.

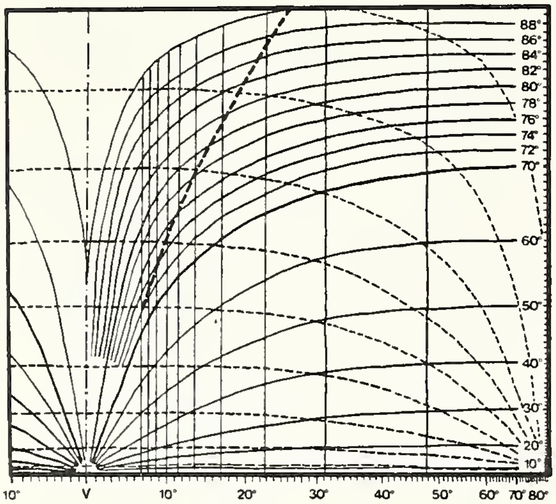

Fig. 4 Daylighting evaluation diagram.

## 4. CONCLUSION

The pressure to accomodate greater commercial densities, and the pace of current development which led to the current reexamination of Midtown zoning standards, are phenomena that are being experienced in many other American cities. At the same time, the desire to maximize daylight for interior illumination due to increased energy costs, and public concern for the quality of streets and outdoor spaces have combined to form a renewed interest in maintaining urban standards for daylight. The proposed Midtown performance approach is a response to this concern that reintegrates daylighting into a comprehensive zoning resolution.

While the values chosen for this approach are specific to Midtown Manhattan, other urban environments with differing historical development patterns would produce different values. However, the methodology developed here can be used by other cities to insure a high degree of environmental quality while encouraging creative urban design practices.

## 5. ACKNOWLEDGEMENT

The 1980 proposed bulk regulations for Midtown Manhattan were developed by Davis, Brody and Associates, and Kwartler/Jones, with Harvey Bryan as daylighting consultant, for the New York City Department of City Planning's Midtown Development Task Force. Preparation of this paper was funded by a grant from the Design Arts Program of the National Endowment for the Arts, with partial support through an inter-agency agreement with the U.S. Department of Energy's Solar Cities and Towns Program.

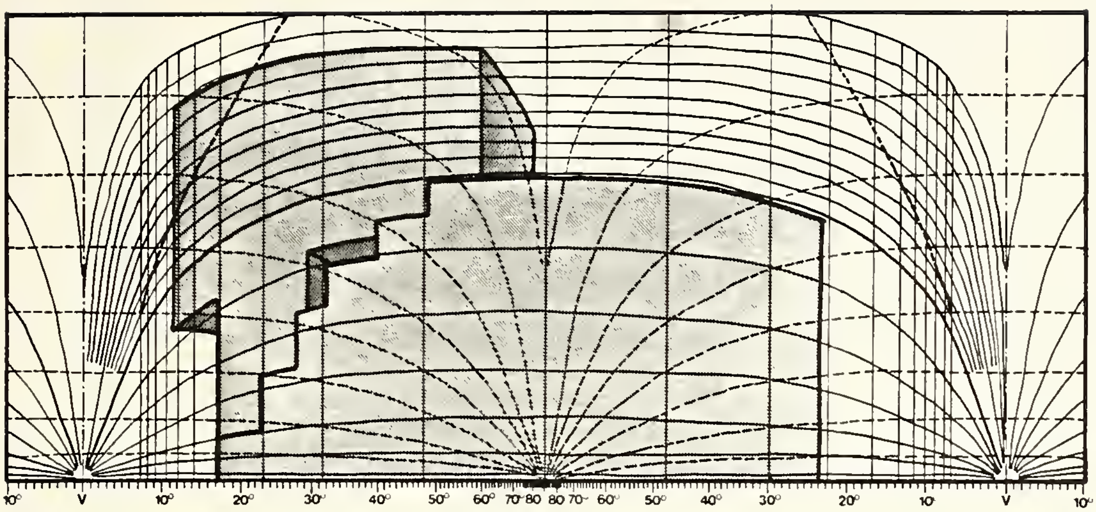

Fig. 5 Daylighting evaluation diagram for the Citicorp Center as seen from 53rd Street, shaded area represents the building's bulk.

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# PEDESTRIAN LEVEL WINDS: A BRIEF REVIEW

By Frank H. Durgin,[1] M. ASCE, and Alfred W. Chock[2]

**ABSTRACT:** The use of analytical and wind tunnel techniques and their limitations for making estimates of pedestrian level winds on or around a building site is reviewed. Some examples of solutions to wind problems both with and without wind tunnel studies are given.

## INTRODUCTION

Tall buildings induce changes in local ground winds. The magnitude of these changes varies from site to site. Adverse changes in pedestrian level winds can make activities such as strolling, shopping, entry into a building, or sitting, uncomfortable, difficult, and even dangerous. Amplified pedestrian level winds have sometimes proven detrimental to the financial and aesthetic success of new buildings.

Recognizing the possible environmental impact, many cities now require some sort of pedestrian level wind evaluation of proposed tall building projects. These evaluations often take the form of estimates furnished by a wind engineering consultant. However, when the project is of sufficient scope, controversial, or both, a wind tunnel study frequently is undertaken.

This article provides an up-to-date brief review of some of the techniques and their limitations for making estimates of pedestrian level winds near a building site. A brief survey of wind tunnel ground wind testing techniques used at the Wright Brothers Memorial Wind Tunnel (WBWT), and the characteristic results obtained from such tests is included.

Numerous articles have been written about pedestrian level winds. The bulk of these deal with specific topics i.e. a particular building; the techniques used at a specific wind tunnel facility; pedestrian comfort criteria, etc. Others have already reviewed the field. The most useful of these are the papers of Isyumov and Davenport (14), Lawson and Penwarden (16), Melbourne (18); monographs by Gandemer and Guyot (11), Beranek and van Koten (3); and the book by Simiu and Scanlan (26). Several of the more significant studies of specific projects are

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Note.—Discussion open until January 1, 1983. To extend the closing date one month, a written request must be filed with the Manager of Technical and Professional Publications, ASCE. Manuscript was submitted for review for possible publication on June 10, 1980. This paper is part of the Journal of the Structural Division, Proceedings of the American Society of Civil Engineers, ©ASCE, Vol. 108, No. ST8, August, 1982. ISSN 0044-8001/82/0008-1751/$01.00.

described in the book. The paper by Lawson and Penwarden (16) is of particular interest, because it outlines a procedure for estimating winds without wind tunnel tests. The essentials of this procedure are also given in Simiu and Scanlan (26). The procedure outlined relies on the generalized studies of simple models by Wise, Sexton, and Lillywhite (28). Combining with this is the observation that while areas of high speed winds near building corners move about and often from corner to corner, with changes in wind direction, the magnitudes of the winds in these areas remain relatively constant. What is omitted from the procedure, except in a cursory way, is the effect of the nearby buildings perturbing these corner flows. Such perturbations can be roughly estimated at best.

The most serious shortcoming of the procedure for estimating pedestrian winds is its inability to evaluate any remedy effectively. Experience at the Wright Brothers Memorial Wind Tunnel, M.I.T. (WBWT), indicates that one of the more difficult aspects in pedestrian wind studies is that an effective remedy in one situation does not necessarily have the same effectiveness in similar situations.

In cases where unacceptable ground winds could be detrimental to the financial, or aesthetic success, or both of a project (the cases of shopping malls, office or apartment building entrances), a wind tunnel study should be considered whenever a preliminary study indicates the possibility of unacceptable pedestrian level winds.

A shortcoming of most pedestrian level wind tunnel studies is their sequence in a typical program. Testing usually occurs only after a commitment to the basic massing design has been made, so that only corrective remedies can be suggested. Alleviating serious wind problems often requires basic changes in design. These decisions, however, can only be made by senior design staff personnel. An interesting comment on this aspect of a typical situation is provided by Melbourne (19): "The author will only conduct wind tunnel tests of this type when senior client and architect representation at the wind tunnel can be guaranteed."

The remaining sections consider: (1) The flow around a generalized building (Sec. 2); (2) obtaining the necessary weather information for a study (Sec. 3.1); (3) the wind tunnel test procedure (Sec. 3.2); (4) combining weather and wind tunnel data and the establishment of criteria for excessive winds (Sec. 3.3); (5) determining the critical wind directions for which remedial action is necessary (Sec. 3.4); and (6) some examples of projects and solutions obtained with and without wind tunnel tests (Sec. 4).

## Pedestrian Level Winds in Vicinity of a Generalized Building

In 1965, Wise, Sexton and Lillywhite (28) reported on several investigations of the flow around the bases of buildings, and groups of buildings.

Fig. 1 is a schematic picture of the flow around an isolated building. The wind is directed from left to right and has the velocity gradient shown. First assume the wind is brought to rest on any streamline approaching the upstream face of the building, and the dynamic pressure $[(1/2)\ \rho u^2]$ is recovered. Then let the flow move from high to low pressure along the face of the building. In this way one gets a relatively accurate qualitative picture of the actual flow patterns. Pressure does not tend to be recovered just above the top of the building. Thus, some of the flow near the top of the building moves up along the upstream face and over the top. There is also relatively little pressure recovered near the bottom of the building due to the low velocities there. Therefore a down flow occurs near the bottom. The down flow created by this low pressure field near the base of the building causes the vortex flow shown just upstream of the building. The vortex causes a reverse flow just upstream of the building (c in the Fig. 1). The vortex it should be noted is stretched and intensified as it is swept around the corner of the building, causing the intense velocity signatures shown in the plan view (d in the Fig. 1). This is the "intense velocity signature" that moves both locally, and from corner to corner, with changes in wind direction as shown. The maximum velocity within the signature varies only about 15% (16). Clearly, the strength of the vortex upstream of the building is associated with the pressure gradient on the upstream face of the building. The strength is thus related to the gradient of velocity with respect to height in the wind approaching the building.

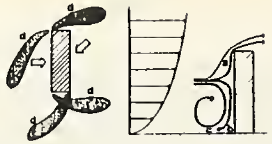


FIG. 1.—Flow Around Single Building

Fig. 2 is similar to Fig. 1, except it includes a second shorter building upstream of the first. Depending on the relative heights, spacing and spanwise lengths of the two buildings, the vortex between the two buildings strengthens or weakens, and may or may not increase the reverse velocity at ground level (c in Fig. 2). Details are given elsewhere (27,28). Finally, the difference between the higher pressures in the stagnating flow in front of the building and the suction pressures on the downstream face of the building will induce high velocity flows in any passageway or opening between the upstream and downstream faces near the base of the building (e in Fig. 2).

## Typical Pedestrian Level Wind Tunnel Study

A typical ground wind study consists of these five parts: (1) An analysis to obtain an estimate of the expected overall wind conditions at gradient height above the site; (2) a wind tunnel test including the measurement of pedestrian

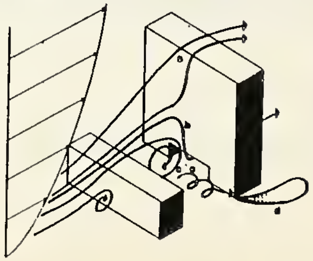


FIG. 2.—Flow Around Pair of Buildings

level winds at a selected number of stations; (3) combining the results of the first and second part to estimate how often a given wind will be exceeded; (4) comparing these results with an established criteria to decide if remedial actions should be taken; and (5) when remedial actions are necessary, finding the critical wind directions and testing the remedial measures.

**Analysis of Expected Wind Conditions.**—It is unusual to have available any wind data directly from a site. In the United States it is common practice to use the data collected from the nearest U.S. Weather Stations. Data may be obtained, for example, from the National Climatic Center in Asheville, North Carolina. The necessary information is the probability that gradient hourly wind exceeds a given speed as a function of wind speed and direction, often for each of the 16 compass directions. The data exists in several forms, the most useful being the winds aloft data. Winds aloft data is taken from balloons at intervals of every 6 or 12 hours. One height where data is usually collected from is 500 m (1,650 ft). This corresponds to the ''gradient height'' near or above the top of the earth's boundary layer, i.e. where there is essentially no further variation of velocity with altitude. Once such 500 m winds aloft velocities are converted to hourly average velocities, they are directly applicable to wind tunnel data. This is usually in the form of a ratio of local to gradient average hourly velocities.

Winds aloft data is not always available and frequently one must use the one minute average data taken every three hours at most weather stations (usually at the nearest airport). Some words of caution are appropriate: (1) A minimum of four or five years of data is preferable, to reduce the effects of a possible anomalous year; (2) the height at which the data is taken can vary from 10 ft (3 m)–100 ft (30 m), both in time and from station-to-station, with accounting for this occuring by assuming some velocity gradient [a method of doing this is given in Radovsky and Durgin (24)]; and (3) the complete set of data for a given airport may be anomalous. For instance, the data obtained at Newark Airport indicates velocities as much as 30% low when compared with that from LaGuardia and Kennedy Airports less than 20 mile (32 km) away. The data from such stations probably should not be used for any building study.

When winds aloft data is not available, the practice at the WBWT is to obtain data from several airports within 100 or 200 mile (322 km) of the site. Comparison of such data is made for consistency. While the local terrain may affect the winds at a given station, its effect on gradient winds is not expected to be large. It is necessary to correct such wind data from ground stations first to an hourly average and then to gradient height (25,26). Lawson and Penwarden (16) give an example of the form such data should take.

Whether or not a wind tunnel test is carried out, a wind analysis is essential. From such an analysis one deduces a wind rose defining the probability of a given wind speed occurring from a given direction such as that shown for Logan Airport in Boston (Fig. 3). This wind rose is derived from the raw data, and is not corrected to hourly average or gradient height. In cases where such a need exists, a wind rose for different times of the year can be obtained providing for the most probable wind direction for each season.

**Wind Tunnel Test.**—Once having decided upon a wind tunnel test it is important to ensure that the earth's boundary layer will, in fact, be properly simulated. This planning includes the possible use of different boundary layers for different directions, particularly for simulated sites that are near large lakes and oceans. Reports should include plots of the variation of average velocity with height, of turbulence intensity with height, and of the power spectral density of the longitudinal component of velocity at a point near the ground. In each case the wind tunnel results should be compared with full scale results from the literature which are themselves transformed to the scale of the model used. Lawson and Penwarden (16) make a similar suggestion. Fig. 4 presents some typical comparisons from tests at WBWT.

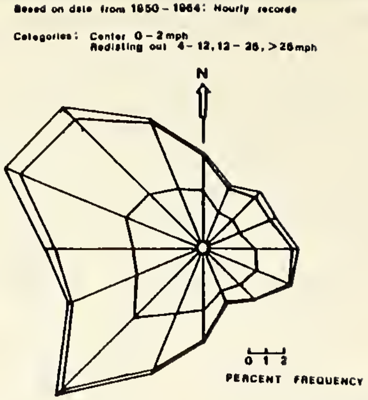


FIG. 3.—Yearly Surface Wind Rose—Boston, Mass. (Logan Airport)

It is unnecessary to have an exact simulation of the earth's boundary layer for this sort of test [while the boundary layer simulation should be generally similar to that suggested by Davenport and Isyumov (8), enough variability exists in the full scale boundary layer daily, due to nonthermal equilibrium that exact simulation provide relatively meaningless precision]. However, since both the turbulence intensity and gradient in velocity will affect the flow near the base of a building, it is essential to have the expected flow approximately simulated. The comparisons between wind tunnel and full scale winds, shown in Fig. 4, are typical of the degree of approximation required.

A model of the terrain and buildings in the immediate vicinity of the building of interest is also necessary. At the WBWT, models are usually constructed at a scale of between 1:300–1:600 and the model of the city around a building out to the edge of an 8 ft (2.44 m) diameter turntable [corresponding to full scale radii of between 1,200–2,400 ft (366–732 m)]. Fig. 5 is a picture of a typical setup in the WBWT. The spires and roughness visible upstream of the model are used to generate the simulated earth's boundary layer.

When measuring pedestrian level winds in the tunnel most investigators use a hot wire anemometer. Measurements include average velocity, the root mean square (RMS) variation about the average velocity, and the peak velocity over a period that is roughly equivalent to one hour full scale. If a longer sample is taken, the peak should be reduced to that equivalent to one hour full scale. Some filtering should also be included in the hot wire setup so that the peak gusts measured are equivalent to 2–3 sec period full scale gusts [Such gusts have

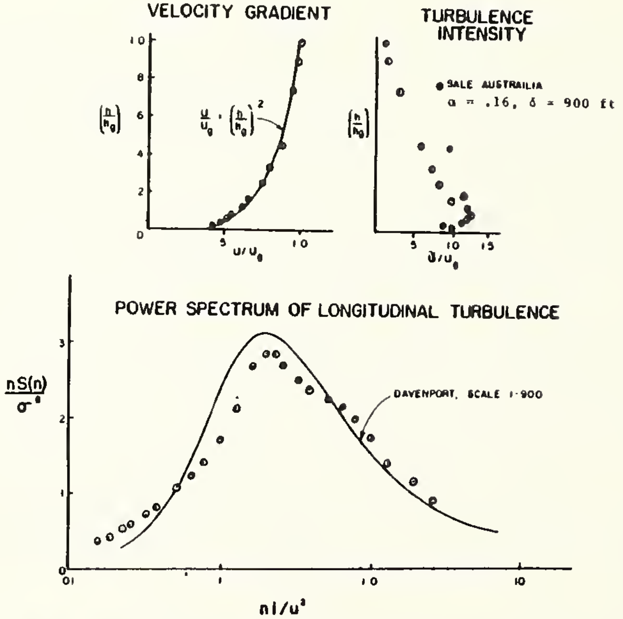


FIG. 4.—Data Showing Validity of Boundary Layer Simulation

been determined by Murakami to be of sufficient duration to affect pedestrians (20)].

The hot wire is probably the most practical instrument available today for making pedestrian level measurements, but it is far from ideal. Bradbury (4) has shown that for turbulence intensities greater than 20%, hot wires become inaccurate (indicate a high average and low RMS velocities) although there is some data (19) to indicate that the measured peak velocities are accurate.

Other systems used to measure pedestrian level winds in a wind tunnel include:

1. The "little men" used by J. Bicknell for a study of the Green Building at MIT (1).

2. The nylon balls on a string used by Davenport, et al. (7) in the Commerce Court study.

3. A technique based on interpreting erosion patterns formed by the saltation of fine grain patterns spread uniformly on a smooth ground plate (15).

4. Pitot-static velocity measurements used by Melbourne (19). These have the disadvantage of measuring only the average velocity. Furthermore, for large turbulence intensities, the measured average velocity will be high:

$$\bar{u}_m = \sqrt{\bar{u}^2 + \bar{u}^2} \qquad (1)$$

in which: $u_m$ = measured average velocity; $\bar{u}$ = true average velocity; and $\bar{u}$ = rms variation about the average. This however may turn out to be an advantage, as we shall see in the next section.

**Combining Wind Tunnel and Weather Data.**—At first glance there seem to be as many ways of combining wind and weather data as there are investigators. However, if one examines each method in detail, they all prove to be similar, when considering only the average hourly wind at each station. The wind data shown in Fig. 3 can be replotted as shown by Fig. 6. $P[\bar{u} > \bar{u}_p]_{\theta_s}$ is the percentage of the time (probability) a given hourly wind velocity ($\bar{u}_p$) will be exceeded in the sector defined by $(\theta_s - \Delta\theta) \le \theta \le (\theta_s + \Delta\theta)$ ($\Delta\theta$ = 11.25 degrees if 16 compass directions are used), where $\theta$ is an arbitrary wind direction. If $P[u > \bar{u}_p]_{\theta_s}$ is summed over all sectors, one obtains the total probability that $\bar{u}_p$ will be exceeded, as a function of $\bar{u}_p$.

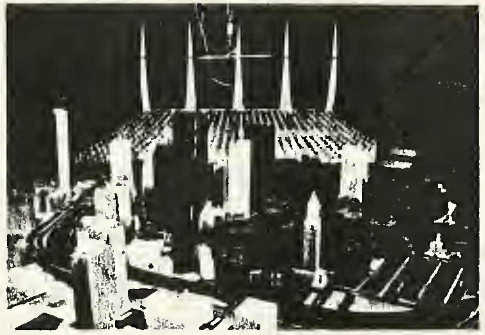


FIG. 5.—Typical Pedestrian Level Wind Study Set-Up at Wright Brothers Wind Tunnel—M.I.T.

Common practice is to fit the wind data for each of the 16 compass directions using the Weibull (12) distribution function which has the form

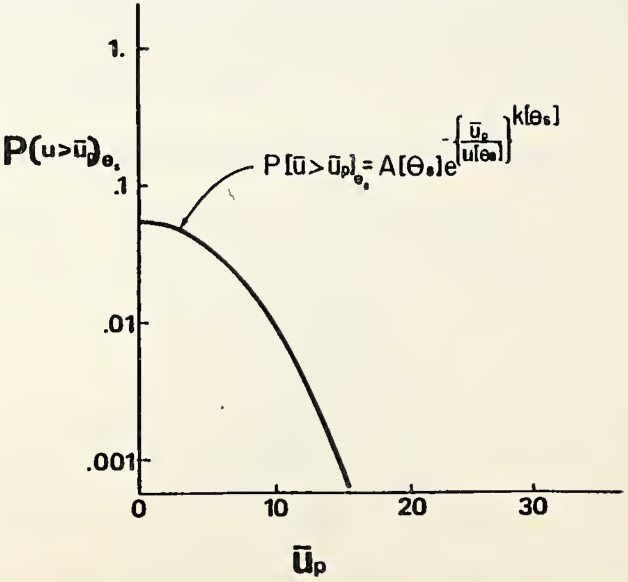


FIG. 6.—Probability of Wind Velocity $u$ Exceeding $\bar{u}_p$ in Given Direction $\theta$

$$P[\bar{u} > \bar{u}_p]_{\theta_s} = A[\theta_s]e^{-(\bar{u}_p/u[\theta_s])^{K[\theta_s]}} \quad \dots\dots \quad (2)$$

in which $P[\bar{u} > \bar{u}_p]_{\theta s}$ = probability of the wind velocity $\bar{u}$ from sector $\theta_s$ exceeding velocity $\bar{u}_p$; $A[\theta_s]$ = Weibull distribution constant, i.e. the total probability of the wind originating in sector $\theta_s$, (by definition, $\Sigma_{N=1}^{N} A[\theta_s] = 1$); $K[\theta_s]$ = Weibull's distribution shape factor determined from least square fit to actual wind data; and $u[\theta_s]$ = scaling velocity on the Weibull distribution which is determined from least square fit to actual wind data.

The WBWT has found that the Weibull formulation does not always fit actual wind data particularly well. Instead use is sometimes made of an empirically derived formula which gives a better fit to the data and has the correct form in the limit.

Once $P[\bar{u} > \bar{u}_p]_{\theta_s}$ is defined for the average hourly gradient winds, one can use the ratio of the average hourly velocity at each station to gradient velocity as measured in the wind tunnel to obtain $P[\bar{u}_p > \bar{u}_p]_{\theta_s}$ over all angles for each station.

In a recent paper Murakami, et al (21) showed that one obtains good agreement between results obtained, as previously indicated, and those actually measured at several ground wind stations near a tall building.

Having found how often an hourly average wind will be exceeded at each station, it is next necessary to establish a criteria for excessive winds.

Different investigators propose their own criteria. However, by combining the standards of the individual investigators, certain general criteria seem to have emerged (18):

1. Average winds greater than 66 ft/sec (20 m/s) are dangerous.
2. Average winds greater than 33 ft/sec (10 m/s) make walking difficult.
3. Average winds greater than 16 ft/sec (5 m/s) make standing or sitting in one place uncomfortable.

A number of investigators have pointed out that the gustiness of the wind also contributes to discomfort. Therefore, its effect should be included in any criteria. Typically, this is accomplished by defining an effective velocity

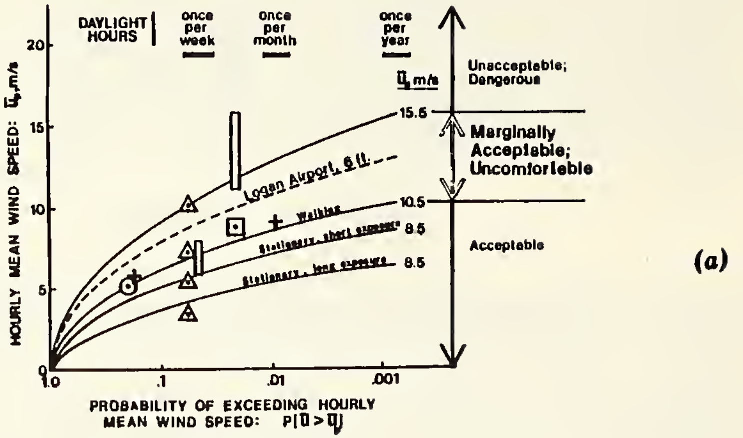
$$\hat{u} = \bar{u}\left(1 + k\frac{\tilde{u}}{\bar{u}}\right) \quad \dots\dots \quad (3)$$

in which: $\hat{u}$ = effective wind velocity; $\bar{u}$ = hourly mean wind velocity; $\tilde{u}$ = rms variation; and $k$ empirical gust factor constant.

Values of $k$ of 1, 1.5, 3, and 3.5 have been suggested. Most of the values are the result of logical reasoning, but the value of 3.0 was derived from the results of some experiments by Hunt, et al. (13) in a wind tunnel. They exposed a number of people to steady and gusting winds, and evaluated their reactions by means of both questioning and measurements. However, only a single frequency was used for the gusts, and it was in the high frequency end of the typical wind spectrum where there normally is not much energy. Thus, it would seem one should not use the total turbulence intensity as measured in the wind tunnel with $k = 3$. As pointed out before the use of a pitot static measurement for $\bar{u}$ includes some of the effect of $\tilde{u}$, ($k = 1$), but only the increase in average force a person would feel, not the peak force. The question of what $k$ to use with the turbulence intensity as measured in the wind tunnel has yet to be resolved.

Melbourne (18) in a recent paper reviewed the average velocity criteria suggested by several authors and put all the results in the probabilistic terms shown in Fig. 7. In his original figure Melbourne also includes data using $k = 3.5$. That data has been omitted from the figure. Note that the effect of a nominal turbulence intensity is included in this figure when the criteria are derived for average velocities with some nominal turbulence intensity assumed [for example, $(1 + k\,\tilde{u}/\bar{u} = 1.5)$]. Thus, the dangerous $\bar{u}$ = 50 ft/sec (15.5 m/s) ocurring once a year implies $\hat{u}$ = 75 ft/sec (23 m/s), a gust which is of sufficient strength to knock people over.

The four solid lines in the figure represent Melbourne's criteria. Line I rep-



| | | SYMBOL |
|---|---|---|
| CONDITIONS AT LOGAN AIRPORT | | ---- |
| CRITERIA | | |
| MELBOURNE (18) | | —— |
| DAVENPORT (5) | | |
| Acceptable for: | | |
| Walking fast | If $P[\bar{u} > 10] < 0.05$ | ⚠ |
| Strolling | If $P[\bar{u} > 7.5] < 0.05$ | ⚠ |
| Standing, Sitting, Short Exposure | If $P[\bar{u} > 5.5] < 0.05$ | ⚠ |
| Standing, Sitting Long Exposure | If $P[\bar{u} > 3.5] < 0.05$ | ⚠ |
| PENWARDEN AND WISE (23) | | |
| Acceptable | If $P[\bar{u} > 5] < 0.2$ | ⊙ |
| LAWSON (17) | | |
| Acceptable | If $P[\bar{u} > 6 \text{ to } 8] < 0.04$ | ▭ |
| Unacceptable | If $P[\bar{u} > 11 \text{ to } 14] < 0.02$ | ▭ |
| HUNT, POULTON & MUMFORD (13) | | |
| Acceptable for Strolling | If $P[\bar{u} > 6] < 0.1$ | + |
| Acceptable for Walking | If $P[\bar{u} > 9] < 0.01$ | + |
| RADOVSKY & DURGIN (24) | | |
| Acceptable | If $P[\bar{u} > 9] < 0.02$ | ⊡ |

(b)

**FIG. 7.—Comfort Criteria: (a) International Pedestrian Comfort Criteria; and (b) Legend for Comfort Criteria Graph**

resents the maximum threshold of acceptability above which all pedestrian activities are dangerous. Line 2 represents the maximum threshold of walking comfortably. As noted in the figure, the mean wind speeds and probabilities found in the area between lines 1 and 2 are classified as "minimally acceptable or uncomfortable for walking." Those found below line 2 are classified as "acceptable for walking." Lines 3 and 4 represent thresholds below which activities entailing short and long stationary exposures, respectively, are acceptable. Added to the figure is a dotted line representing conditions at the six foot elevation at Logan Airport, in Boston. The various other symbols are those of other investigators [5,13,17,18,23,24]. Included are some results on the left from Davenport (5,6). Davenport has found a way of estimating the number of occasions a given velocity could be exceeded. This is different than $P[\bar{u} > \bar{u}_p]_{\theta_s}$, which does not account for the fact that a given wind generally blows for an appreciable amount of time.

The criteria developed for the New York City study of Battery Park, carried out at WBWT (23), was based on walking to and from Battery Park City. It is a result of the experience of Battery Park City employees at the entrances of their building and the estimates of how often a 20 mph (8.94 m/s) wind would be exceeded.

Fig. 7 provides a good way of comparing the various criteria, but using a series of such plots to evaluate a plaza, etc. for an architect or engineer makes the data difficult to present and interpret. If one observes that the shape of each of the curves is much the same and determined by $K[\theta_s]$, and that different criteria merely mean essentially amplifying or attenuating the other criteria in velocity [i.e. changing $u[\theta_s]$], then it is clear one needs to use only one point on each curve for evaluating the acceptability of the windiness of a station. This has been done by many investigators. On this basis one can pick the 5% value, as Davenport (5,6) has, for example, and point out that this means the given velocity will be exceeded about once per week in the daytime. At WBWT we have used the 2% value, which means the event will occur about once in two weeks. The 2% figure leads to velocities of about 4, 6, 8, and 12 m/sec for Melbourne's four criteria.

An error is introduced in correcting the one-minute averages derived from weather data to hourly averages when a simple constant is used. This error is greatest for velocities that are exceeded more than 10% of the time. Thus, using a single percentage of 5% or less tends to minimize this error.

Melbourne (18) says, "It seems reasonable to conclude that assessments based on any of these criteria (in his figure) could be made with some consensus of international opinion." However, once the problem of safety has been addressed satisfactorily, the actual response of people to wind in a given area will be somewhat dependent on what they expect and are accustomed to.

At WBWT an alternate method of evaluating wind gustiness is also used, comparing the relative strength of the peak gust in terms of the average and RMS. This derived quantity, known as the gust strength factor for a single wind direction of a ground station point, is given by:

$$g[\theta] = \frac{u' - \bar{u}}{\tilde{u}} \quad \text{.......................................} \quad (4)$$

in which: $g[\theta]$ = gust strength factor for direction $\theta$; $u'$ = peak measured velocity; $\bar{u}$ = average measured velocity; and $\tilde{u}$ = RMS velocity.

The total gust strength factor at a ground station point, $g_{tot}$, is defined as the summation of the product of the individual gust strength factors from a single direction, $g[\theta]$, and the probability of the wind originating from that direction, $A[\theta]$:

$$g_{tot} = \sum_{n=1}^{16} g(\theta)\,A\,[\theta] \quad \text{.......................................} \quad (5)$$

This total gust strength factor is essentially a weighted average.

For average conditions, the effect of gusting is already included in Melbourne's criteria. However, for unusual conditions—where $g_{tot}$ is larger than those of surrounding points—gustiness may be an additional factor. Coupled with a high peak wind velocity, a high $g_{tot}$ factor indicates rare, but strong gusts. These occurrences cannot otherwise be inferred by using the aforementioned probabilistic results.

Finally, since most weather data can be obtained on magnetic tape, one can examine seasonal, temperature, and other effects if they are of interest to a particular project.

**Taking Remedial Action.**—If the evaluation of a particular station shows it to be too windy, one first finds which wind direction or directions contribute the highest probability. Corrective action then is taken for winds from those directions. At WBWT the contribution of each direction to the total of 2% probability, for each station, is given as part of the basic results. In Section 4 it is assumed that we have taken these last steps and have identified both the station or areas of unacceptable windiness and the wind directions contributing to the highest probability of the unacceptable winds.

## SOME EXAMPLES OF WIND PROBLEMS AND SOLUTIONS

Examples from the Boston area provide demonstrations of: (1) An attempt to solve a wind problem without a wind tunnel study; (2) a case for which an existing wind problem was solved with a wind tunnel study; and (3) a case where a wind tunnel study was used to find a potential problem and its solution.

**Prudential Center Shopping Mall.**—Fig. 8 is a plan of the Prudential Center in Boston. The complex is composed of a 52 story tower which is the focus of the development, a surrounding landscaped mall, the twin 29 story Sheraton Hotel, two department stores, a 25 story office building, and three 26 story apartment buildings (one, The Gloucester, is not depicted). All of these structures are located in a 31 acre development. The Center was dedicated in 1965, and was designed before there was a general awareness of the possible pedestrian level wind problems that a tall building can induce.

The shopping mall (shaded area in Fig. 8) consists of two rows of stores on the east and west sides of the plaza. These two lines of stores were separated by the 52 story tower, an open exhibition plaza to the North and the skating rink to the South.

As originally constructed, the only protection provided shoppers was a 20 ft (6.1 m) wide overhanging canopy along the fronts of the stores, running the

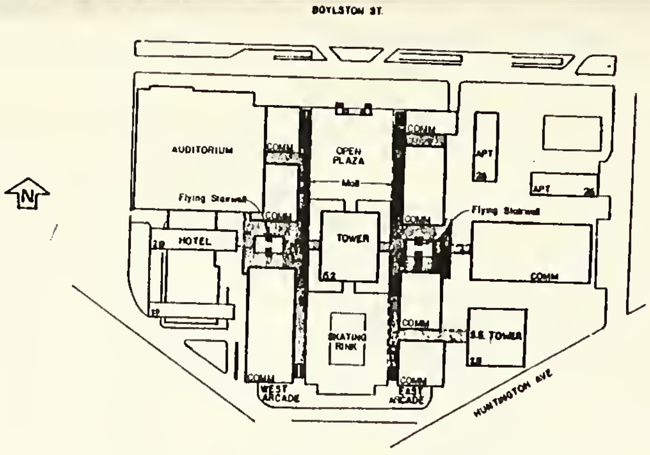


FIG. 8.—Prudential Center, Boston, Mass. Site Plan

entire length of each set of stores. The winds made shopping in the mall area quite uncomfortable in the winter. A vertical wall was added to the outside of the canopy, completely enclosing the walkways except at the flying stairways and the North and South entrances of each walkway.

Enclosing the walkways improved the situation in each of the newly created corridors, but cold winter winds still blew the entire length of the enclosed walkways. In the early 70's doors were added at the ends of each of the walkways to form the existing configuration. This solution provides adequate shopping comfort. However, the current situation can be improved.

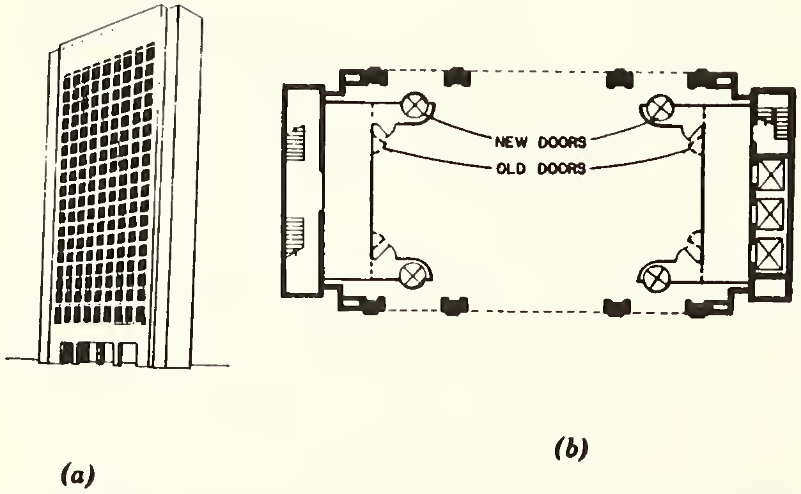


FIG. 9.—Test Sites: (a) Green Building, MIT; and (b) Green Building—Ground Level Plan

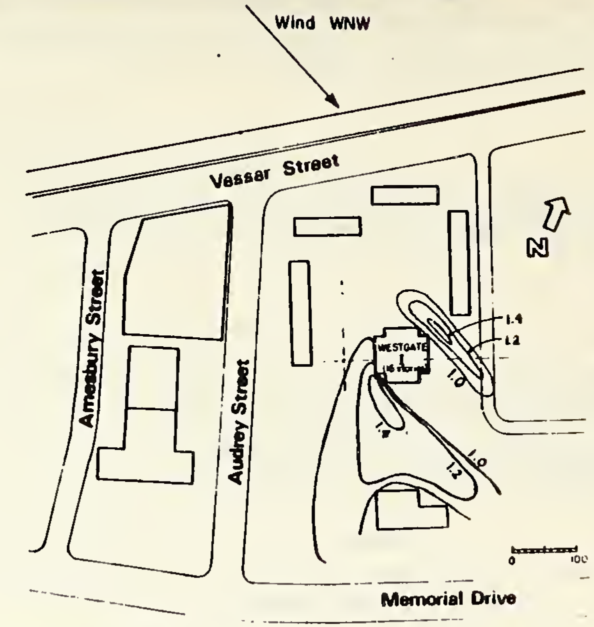


FIG. 10.—Measured Velocity Ratios—Campus with Westgete I

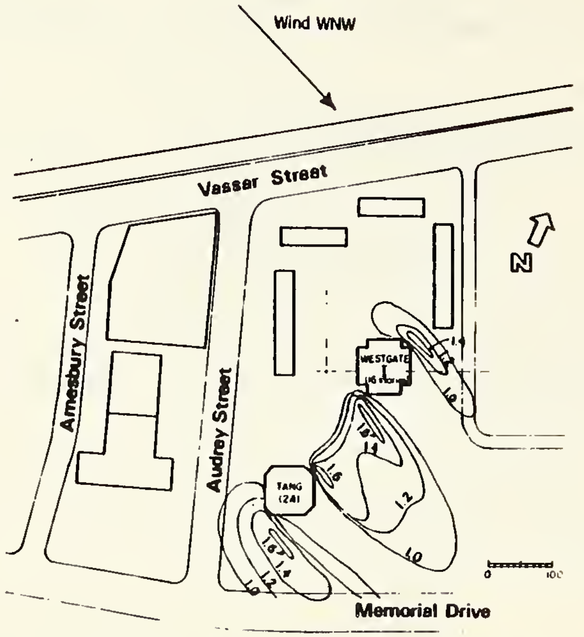


FIG. 11.—Measured Velocity Ratios—Campus with Westgete I and Tang Hall

**Green Building at MIT.**—The Green Building at MIT (see Fig. 9(*a*)) was built in the early 1960's. It has 17 stories and is placed roughly at the center of the MIT campus. It is the only tall building in the vicinity. The entrances were originally located in the side walls, facing the inside of the two-story opening through the building at ground level (see Fig. 9(*b*)).

Serious wind problems were encountered by those entering or exiting the building. The wind problem for the Green Building is one of the classic cases reviewed previously. Studies of this building sparked some of the early interest in wind tunnel studies of pedestrian level winds (1,2).

The broad sides of the building face roughly north and south, so that the typical northwest winter winds (refer to the Boston wind, in Fig. 3) caused a vortex upstream of the North side as well as high winds in the opening through the base of the building, in the vicinity of the doors.

Tests were initiated in the WBWT in 1965 (2) to determine what could be done to reduce the winds. Canopies and screens, for example, were tried (1). While evaluating these several schemes quickly Bicknell invented his "little men" (1). The solution was to move the entrances from the inner sidewalls to revolving doors facing the opening of the passageway through the base of the building, as shown in Fig. 9(*b*).

The entrances are now located near the stagnation region where the flow reverses direction due to the upstream vortex. The winds here are much lower. Otherwise, the situation has been left relatively unchanged. The solution did not eliminate the wind, but instead made it unnecessary for people to walk in regions of strong winds.

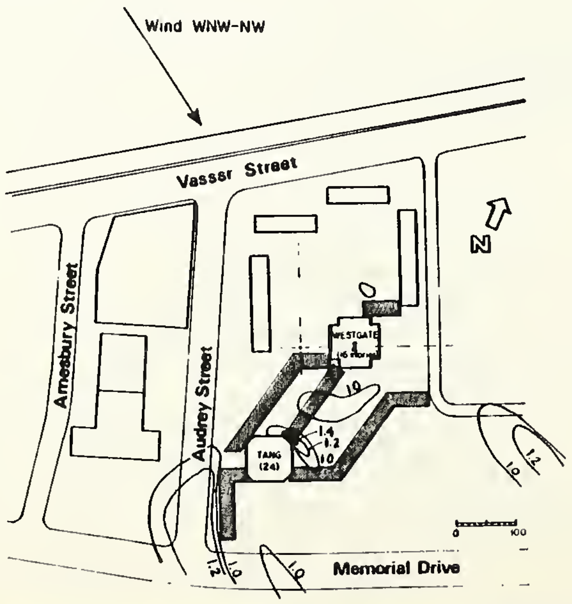


FIG. 12.—Measured Velocity Ratios—Campus with Westgate I, Tang Hall and 35 ft Evergreen Hedges

**Tang Hall MIT.**—Tang Hall is the second of two high-rise dormitories in the Westgate complex at the west end of the MIT campus.

The pedestrian level wind study of Tang Hall at MIT is an example of a wind tunnel test that was run to identify the wind problems before the project was started. The study was carried out in two parts. The first in 1970 (9) identified the problems. The second, in 1972 (10) confirmed the solutions.

At the time of the first study, Westgate I (16 stories) and the low buildings to the north already existed (Fig. 10). The areas near the southwest and northeast corners of Westgate I were known to be windy because residents complained. As is typical in Boston, the northwest winds caused the problem. Only the results for the northwest winds are shown in Fig. 10. The contours indicate areas where the wind has been amplified by the presence of the buildings. The ratios of 1, 1.2, 1.4 show the increased wind velocity. Fig. 11 shows similar results for the complex with Tang Hall added. Both the areas inside the contours and the magnitude of the amplification of the winds have been increased.

The shape and approximate position of the building had been committed, so that recourse was taken to using landscaping to alleviate the obviously unacceptably windy areas. Fig. 12 shows results for northwest and north-northwest winds when adding three rows of 35 ft (10.7 m) high evergreen trees. With the exception of the area just to the northwest of Tang Hall, the trees reduce the amplification of the winds to less than 1.

The trees have now been planted and do alleviate the situation considerably. However, they are only 20 ft (6.1 m) tall and are not placed exactly as modeled in the test.

## Conclusions and Summary

1. The presence of high rise buildings in the city can have an adverse effect on local winds. In some cases, *amplified* pedestrian level winds have impaired the financial and aesthetic success of a building.

2. In cases where adverse ground winds may pose a serious problem, pedestrian level winds may be appraised by a wind engineering consultant. In the case of a sufficiently large or controversial project, a wind tunnel test should be made.

This paper has shown both the methodology and usefulness of pedestrian level wind studies with and without the use of a wind tunnel. A limited list of references has been included.

## Acknowledgment

The authors wish to thank Michael Rosenbaum of the Prudential Center Management Corp. for his information on ground wind problems at the Prudential Center Shopping Mall in Boston.

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## APPENDIX II.—NOTATION

*The following symbols are used in this paper:*

$A[\theta_s]$ = Weibull distribution function constant—total probability of wind originating from sector defined by $[(\theta_s - \Delta\theta) < \theta < (\theta_s + \Delta\theta)]$;

$g_{TOT}$ = weighted gust factor for given station;

$g[\theta]$ = gust factor measured in wind tunnel for wind from direction $\theta_s$;

$k$ = empirical gust factor (definition of $\hat{u}$ following);

$K[\theta_s]$ = shape factor in Weibull distribution function;

$P[\bar{u} > \bar{u}_p]_{\theta_s}$ = probability of $\bar{u}$ exceeding $\bar{u}_p$ in sector defined by $\theta_s$;

$q = 1/2\,\rho u^2$ = dynamic pressure;

$u$ = wind velocity;

$\bar{u}$ = average hourly wind velocity;

$\bar{u}$ = root-mean-square (RMS) variation of velocity about average;

$u'$ = peak velocity measured in wind tunnel;

$\hat{u} = \bar{u} + k\bar{u}$ = effective velocity;

$\bar{u}_m$ = average hourly wind velocity measured by pitot static tube;

$u[\theta_s]$ = velocity scaling factor in Weibull distribution for angle $\theta_s$;

$\theta$ = wind direction angle;

$\theta_s$ = nominal wind direction (usually one of 8, or 16 compass points); and

$\Delta\theta$ = one-half of angle between compass points (22.5° for 8 compass points, 11.25° for 16).

# Daylight in Manhattan

## *How inventive zoning can give city-dwellers their fair share of the sun.*

*By James A. Moore*

If natural light replaces the use of electricity in large buildings, energy consumption will be greatly reduced. But many of our cities are so congested that sun and light only reach the upper levels of the tallest structures. Lower stories, low-rise buildings, and the streets are shaded throughout the day. Now, New York City has moved to reverse this dilemma with a newly proposed set of zoning regulations for midtown Manhattan. The proposed regulations consider both the quantity and quality of natural light reaching the city's streets to be of primary importance. Optimistically, the creators of the proposal feel that the new laws could become the pivotal reference for new zoning ordinances in other American cities. At a minimum, they are certain that the regulations will have two major effects on Manhattan: buildings will consume less energy and the quality of pedestrian street life will improve.

The use of zoning as a means of regulating natural light is not foreign to New York. The city's first set of zoning laws reflected a concern with daylighting. In 1915, the Equitable Life Insurance Company opened the doors of its new headquarters at 120 Broadway and was immediately hit with a wave of protest. The 40-story skyscraper was the tallest building in the city, and it created a canyon of shadows along nearby buildings and streets. Property owners in the area were furious, and their anger at the loss of natural light led to America's first comprehensive attempt at municipal regulation of building development. The ensuing 1916 New York Zoning Regulations literally prescribed the forms now synonymous with midtown Manhattan: the wide avenues, the uniform street wall, the classic skyline punctuated by individual towers such as the Chrysler, RCA, and Empire State buildings.

To prevent the canyon effect, the regulations divided Manhattan into a series of districts, each with a limit on the height of buildings and their street walls. These limits were in direct proportion to the width of the streets that fronted the buildings: for each foot the structure set back from the street, it could rise an additional number of feet. Buildings were prohibited from impinging on a prescribed "sky exposure plane," an angle measured from the center of the fronting street to the peak of the building. The rise-to-setback ratio and the sky angle plane varied from district to district depending on street width, existing land use, and property values. The two most common districts had rise-to-setback ratios of 2.5:1 and 3:1. These corresponded with sky angles of 68.3° and 71.6°, or an average of 70°. Buildings were permitted to have towers of unlimited height, but these had to be set back a mandatory distance from the street, and could cover no more than 25 percent of the overall lot area.

Over the years, variances and the changing needs of the city decreased the effectiveness of the 1916 ordinances. In 1961, partially in response to these needs and partially as a final reaction to the "wedding cake" shape of the skyline—created by less-imaginative builders trying to comply with the 1916 laws—the City Planning Commission adopted a completely new type of zoning regulation. A "sky exposure plane" replaced the height districts for governing setbacks. The permissible tower area of a building was increased to 40 percent of the overall lot area, and a new concept, the Floor Area Ratio (FAR) was introduced to control a building's bulk. In the initial design, the floor area of a proposed building could be no greater than 15 times the overall lot area. However, by providing outdoor amenities such as plazas, builders could get the city to raise the allowable FAR up to 18. Developers and designers soon found that the new ordinances favored tall, monolithic structures: towers and slabs. Although the effect of these buildings on daylighting levels was not drastic, city planners quickly began to feel that the isolated structures were destroying the existing character of the city. The Planning Commission responded to this dilemma by expanding the Special Permits section of the zoning regulations to include interior amenities. Now, if a new proposal included items such as arcades or mid-block passageways, its FAR could go as high as 21.6. This "incentive zoning" was an attempt to promote buildings which, once again, assumed their traditional role of defining the public space of the street. However, the discretionary review process that accompanied incentive zoning was inherently subjective and frequently disregarded the traditional need for light and air to the street. Residents and pedestrians in midtown soon discovered that the slabs and towers produced by incentive zoning did not make good neighbors; the amenities at the base of the buildings did not make up for the height and bulk at the top. Ironically, many of the Special Permit buildings, which rise up straight from the street edge, have no more bulk than earlier buildings in the city; the placement of the bulk, however, has drastically reduced daylight and street space. Joanna Battaglia, head of a community planning board, eloquently expresses the frustrations that many New Yorkers feel: "We are having unwanted amenities foisted on us at the expense of the best amenities of all—light and air."

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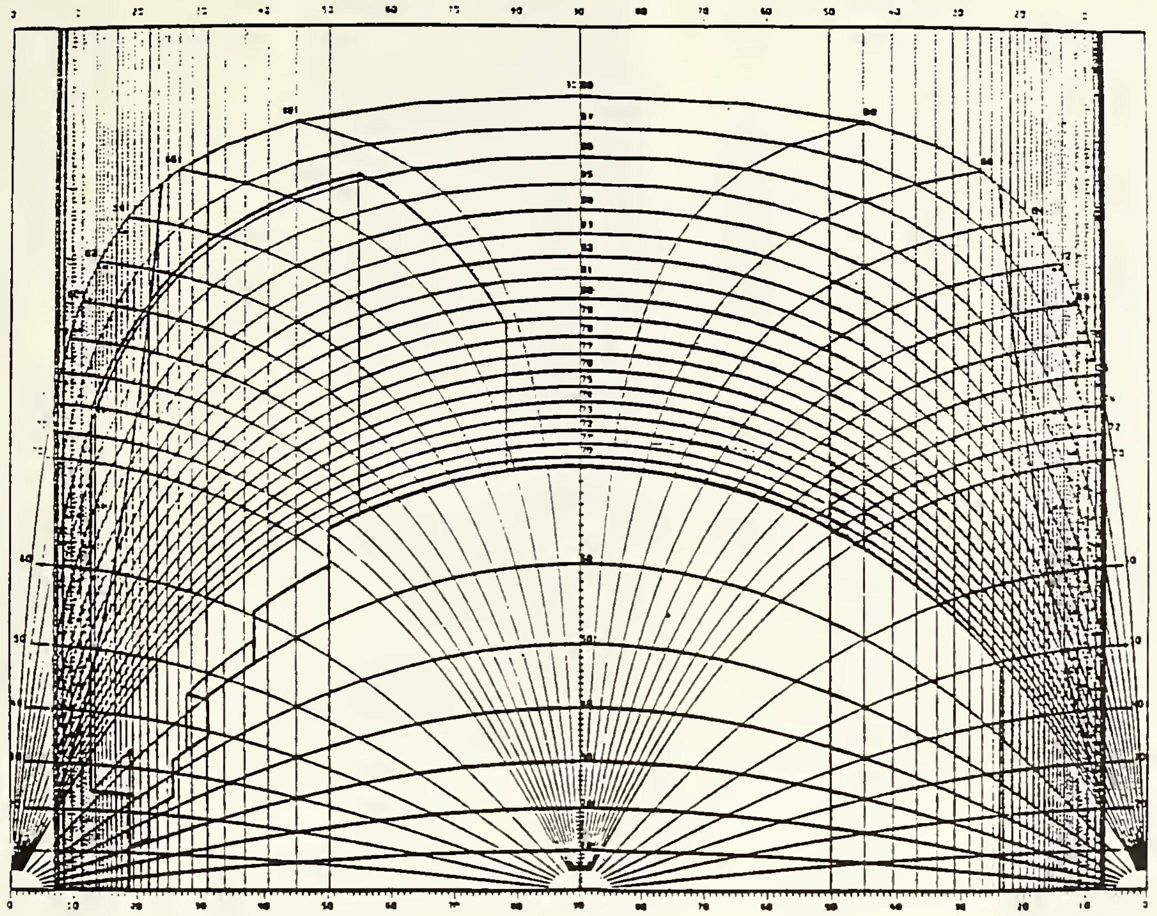
*James A. Moore is a free-lance writer and a researcher associated with the Laboratory of Architecture and Planning at MIT.*

America's first comprehensive zoning law in 1916 guaranteed minimum standards of light and air for New Yorkers. Fifth Avenue was designated a lower height district, which meant more light could reach the street. One rule allowed towers of unlimited height, if they were set back the required distance from the street and occupied no more than a quarter of the overall lot area. The design community responded with such buildings as the



DAYLIGHT EVALUATION CHART; 60 FOOT STREET (COPYRIGHT, 1981)

# DAYLIGHTING TEST

The daylighting performance test attempts to quantify the amount of natural light that will reach the street after a proposed project has been built. Light to the street is measured on a Daylight Evaluation Chart, which is a modified version of the Waldram diagram developed in England during the 1930's to aid in daylighting analysis. The modified diagram is a graphic representation of a three-dimensional view of a building; it presents a slightly distorted version of a proposed project as it would be seen by a pedestrian standing at either end of the street fronting the building. The variable grid prestamped on the diagram helps quantify lighting levels. Each square represents two vertical degrees of sky and 25 feet of lot frontage at the street line, so that for a site occupying 250 feet of street length, a full 100 available daylight squares would become the basis for evaluating daylight performance. The consultants distorted the grid to give greater value to daylight coming from higher in the sky realizing that "below the range of prevailing street walls in midtown, there is little expectation of seeing the sky." They determined that the average street wall height presently found in Manhattan occurred at approximately a 70° angle above the ground measured from the center of the fronting street. Therefore, they divided their diagram at the 70° point. Above this level, the grid is divided into 100 blocks whose size varies in relation to the "quality" of the light coming through these areas. Unobstructed blocks above the 70° line are multiplied by their weighted value, totaled, and subtracted from 100. Blocks below the 70° line are similarly multiplied, but their weighted values are less. These values are also totaled and added to the original figure; the sum of the two figures represents the building's final daylighting score.

## Citicorp Center Score

| | |
|---|---|
| Available Daylight Squares | 128 |
| Squares Blocked Times Value | −40.23 |
| Squares above 70° blocked | 13.8 |
| Squares below 70° open | −1.6 |
| Total blockage | −42.3 |

Daylight Score

$$\frac{128 - 42.3}{128} = 67\%$$

Using reflectivity to increase score R, (reflective rating) of the building:
aluminum = .85 (60% of building surface)
solar ban glass = .38 (40% of building surface)

Reflectance

.85 × 60% + .38 × 40% = .662

Then determine building face orientation:

36 squares face S, SW
4.23 squares face E, SE

orientation value S, SW = .93
orientation value E, SE = .72

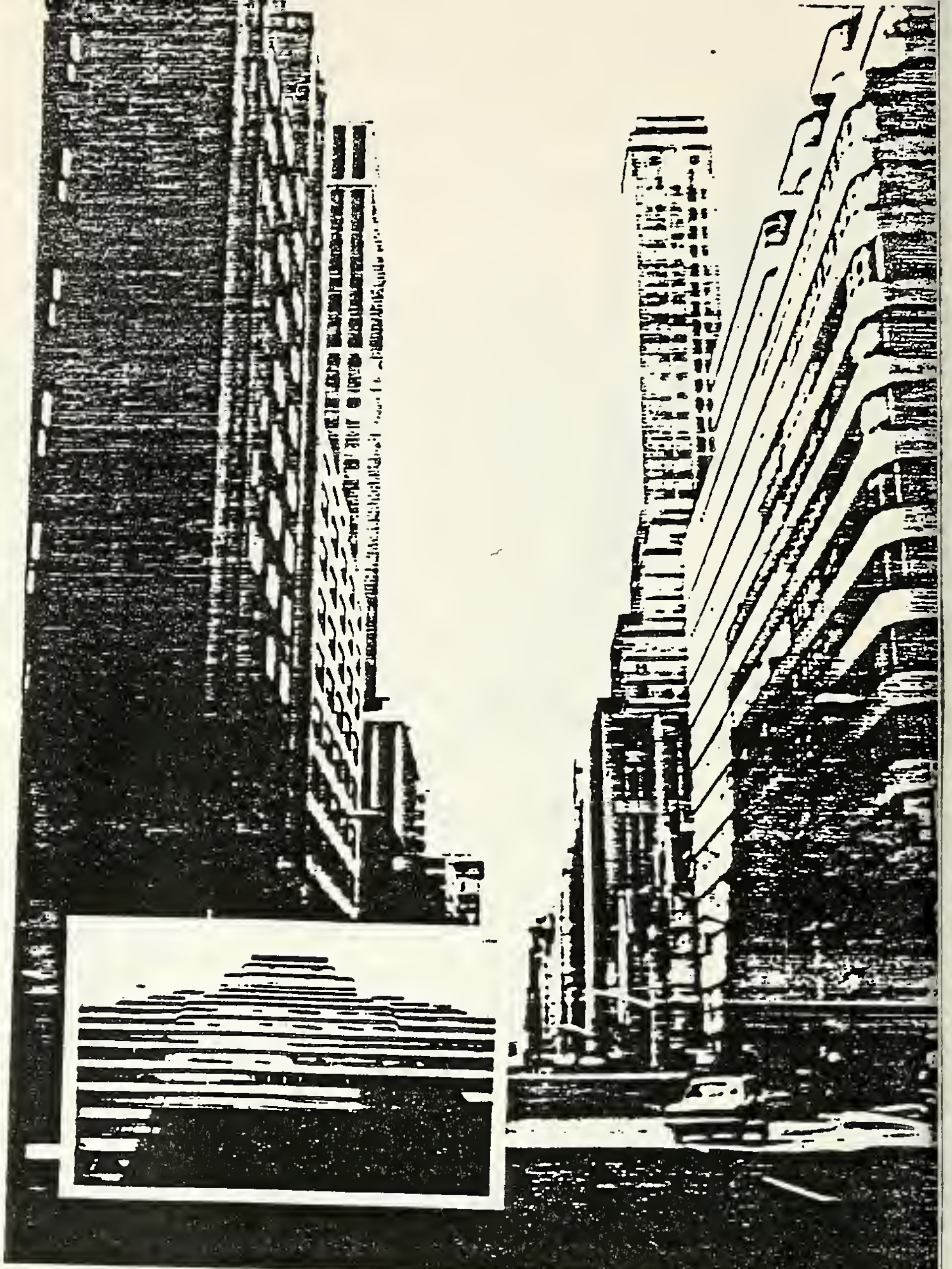
Formula:
reflectivity=(R, − .15) × (O, × number of squares)
Reflectivity for S, SW=(.662 − .15) × .93 × 36 squares=17.14
Reflectivity for E, SE (.662 − .15) × .72 × 4.23 squares=1.56
Total 18.70
Now apply reflectivity adjustment to original score
128 − 42.3 + 18.7 − 128=81.5%
Therefore, light materials increase the score for the building 14.5%

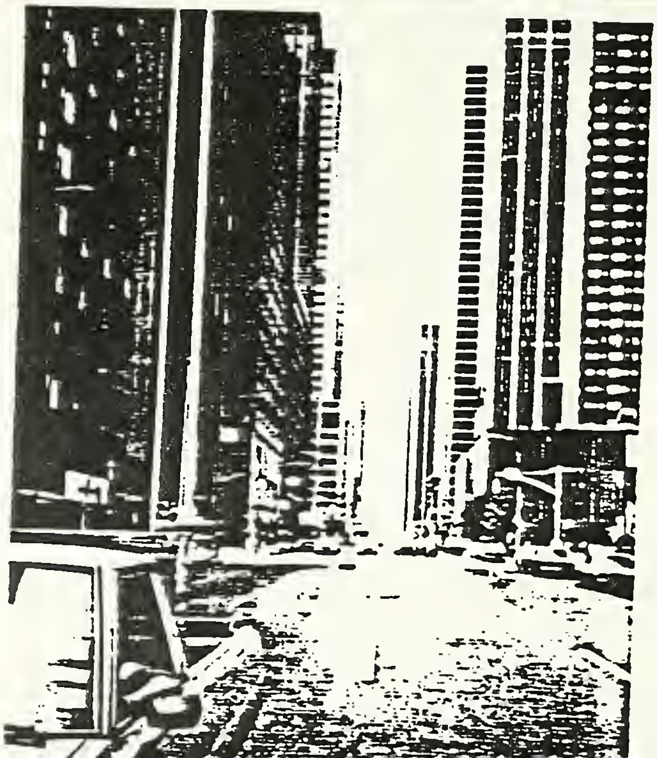
In 1979, the city authorized a study to revise the existing regulations. Much of the work for the recently published report was done by Kwartler/Jones, Architects and Davis, Brody & Associates. Their Height and Bulk Proposal returns to the spirit of the 1916 regulations. Once again, admission of light and air to the street are primary zoning considerations, but the new ordinances specifically avoid dictating any particular building shape or form. Instead, the new proposal is based on a standard of daylight and openness derived from the actual conditions which existed in midtown Manhattan—many of which were the direct result of the first 1916 regulations. The consultants made considerable efforts to ensure that today's architects will have as much design freedom as possible in creating buildings that comply with these conditions.

Shortly after it received the city's contract, Kwartler/Jones hired Harvey Bryan as a consultant. Bryan, currently a professor in the Department of Architecture at MIT, had done a good deal of lighting research and was a staunch advocate of urban daylighting. Initially, the team was asked to explore the merits of the "solar envelope" urban design concepts developed by Ralph Knowles. The solar envelope for a particular location is defined as the three dimensional space that a building can occupy without casting a shadow on neighboring buildings or property. The goal of envelope-based zoning is to ensure year-long solar access to every building within its jurisdiction. Very quickly, the consultants came to the conclusion that Knowles' concept was technically ill-suited to New York City. "Most of the buildings in midtown are internal gain buildings: cooling load dominated. They don't need solar access; in fact most of them need less direct sunlight, not more."

Beyond a certain point, however, too much shading from surrounding buildings becomes a liability to life on the streets. The consultants needed a method of determining the level of daylight, sunlight and shade that was optimal for building energy efficiency and pedestrian life. They began background research to discover historical examples of urban zoning based on daylighting. "Surprisingly, New York's own 1916 regulations were one of the best references," says Bryan. "A lot of studies on urban daylighting had been done in Europe since that time, but little had ever been applied."

The consultants also began assessing Manhattan's existing daylighting problems. They went throughout the midtown area, measuring shadows and taking photographs. To help in their work, they developed a modified version of the Waldram diagram, a graphic tool developed in England during the 1930's. By using this diagram to analyze representative buildings and city blocks, the consultants were

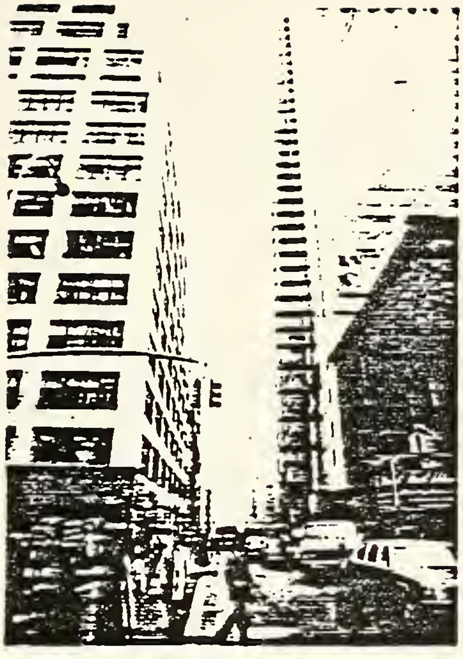




*The 1916 zoning regulations helped create the Manhattan skyline with its slender tower and setback skyscrapers like th tiered Look Building. In reactio to the wedding cake shapes an to address other planning needs, the city revised its zonin in 1961. The Floor Area Ratio was introduced with bonuses for plazas and arcades. Devel opers and architects discovere the new ordinance favored tall monolithic slabs like those that line 6th Avenue (left).*

able to develop a "Daylight Map" of midtown Manhattan. This map was then used to identify the minimum and average expected levels of daylight in midtown resulting from 64 years of zoning regulations.

In June 1980, the consultants handed the Planning Commission a performance-based zoning proposal. According to the proposal, every future building project would be assessed by four criteria: daylighting, street wall height, street wall length, and reflectivity. To receive clearance, the proposed building had to score at least 85 points on a 100-point evaluation. Street wall height and wall length were included as criteria to ensure that new projects would respond favorably to the existing physical characteristics of their surroundings. Reflectivity was an optional criterion. Building designs were rewarded for using light-colored materials on the outside. Daylighting, however, was by far the most important factor in the proposed ordinance. Buildings were judged by the amount of natural light permitted to reach the streets surrounding them, according to a simple, but accurate method developed by the consultants (see box).

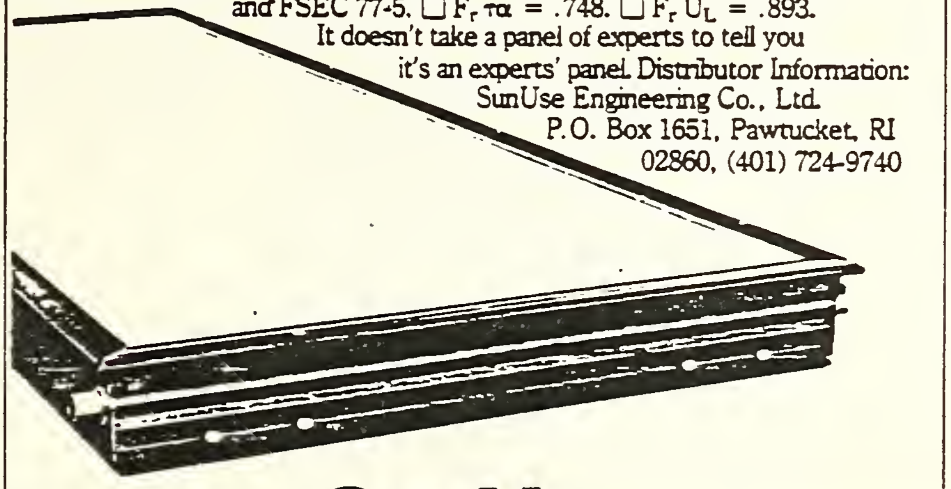


*New York's new zoning proposal could set an example for other American cities. At least, hope the creators, they will reduce building energy consumption and improve the quality of pedestrian street life in midtown Manhattan.*

The Planning Commission had a mixed response. It wanted to increase the quantity and quality of light reaching the street, but it also felt that the proposal, as written, was too confusing for the average architect, builder, or developer. The New York chapter of the American Institute of Architects supported the consultant's approach, but the Real Estate Board of New York, worried about the effect that the regulations would have on future development, told the commission that the new concept was "excessively cumbersome." The consultants rewrote the initial draft deleting much of the technical data and simplifying the performance requirements. The Planning Commission endorsed the revision but still voiced the concern that it was "too cumbersome." The commissioners countered with a two-tiered proposal, which contained a modified version of the consultant's performance approach and an even simpler, although architecturally more restrictive, prescriptive approach. To receive zoning approval, a proposed project would have to fulfill the requirements of only one, not both, of the approaches.

Still, both parts of the city's final report, which was issued during the summer of 1981, are based on daylighting. The performance approach is similar to the consultants' original proposal with minor changes in scoring the four tests. The prescriptive approach is similar in theory to the sky-angle planes of the 1916 ordinance. The approach uses "sky exposure curves," which define the allowable shape and bulk of newly proposed projects.

Although Kwartler is disappointed that a prescriptive approach was included in the zoning report, he is enthusiastic about the outcome, overall. "The performance approach could be turned into a generic model for urban zoning. Street level daylight is an amenity needed in every city. Just as the 1916 regulations became the prototype zoning laws for other U.S. cities, the concepts behind the new revisions could be adapted to other situations. Many Sun Belt cities are expanding rapidly. If they aren't careful today, they will soon have the same problems that Manhattan has. A rigorous set of zoning regulations based on daylighting would greatly protect the basic amenities of these cities." ○



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# Davis Brody & Associates, and Kwartler/Jones, Architects and Urban Planners Associated

**e proposed zoning bulk
ulations for Midtown
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mance system by which a
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**edits**
*hitects and planners:*
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k; Michael Kwartler,
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rector; Alan Schwartzman,
is Brody & Associates,
rector.*
***sultants:** Harvey Bryan,
ight; Ray Masters, computer
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***nt:** New York City Planning
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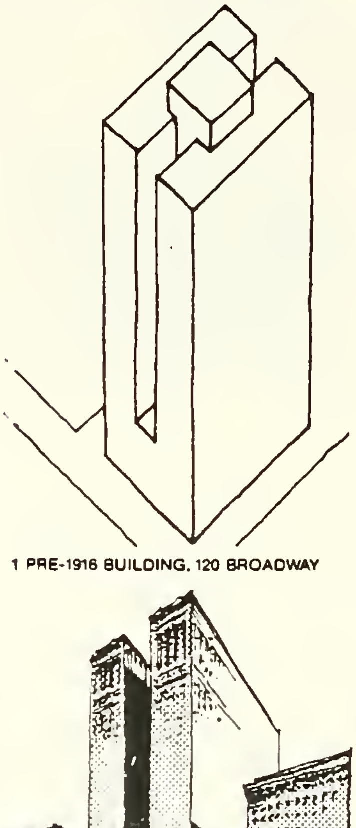
*drawings (right), which are
ner explained in the text
r "program," illustrate the
s of New York's zoning reg-
ons over the years, which ul-
tely led to the new Maximum
t Wall Height ordinance
Daylight Evaluation Chart
rated on the following
s.*

**Project:** New York City Midtown Development Project Bulk Regulations.

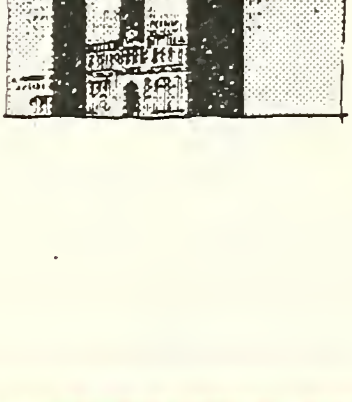
**Program:** To prevent New York's streets from becoming dark canyons, the city's first zoning resolution was passed in 1916. This limited the height to which a building could rise, in proportion to its width on the street, until it had to be stepped back; it created the zoning envelope that was responsible for the typical "wedding cake" New York skyscraper. In reaction to this prescriptive ordinance, and in response to the need for larger office floors, the zoning regulations were completely revised in 1961 in favor of a "sky exposure plane" system based on a building's floor area ratio. This was still prescriptive, and resulted in the typical "tower-in-the-park." However, the 1961 regulations also included for the first time a series of bonuses or incentives, and over time a growing and increasingly complicated series of special districts and permits, which resulted in "super buildings" perceived by the public as environmentally destructive. Because of the variations allowed in the 1961 ordinance, that regulation became, in effect, unused by 1980. By then, every new building in Midtown was going through a lengthy and complex review process, which lost sight of the basic intent of zoning bulk regulations, which were to protect public access to light and air. For the developers and architects, this process, which could take as long as a year and a half, was becoming both extremely expensive and uncertain in its outcome. Environmental and equity issues became increasingly less predictable for them and for the public. As a result, this study was commissioned to develop workable as-of-right building bulk regulations that would deal with the related problems of the 1961 zoning ordinance and its variations, the problem of building context, the environmental quality of outdoor space, and the need to minimize administrative review by streamlining procedures.

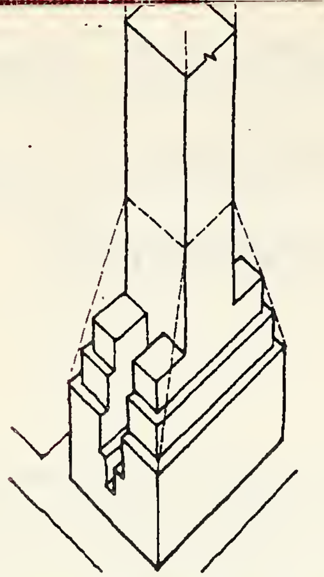
**Site:** Midtown Manhattan, New York.

**Solution:** The proposed zoning regulations constitute a performance zoning system that is made up of three components by which a proposed building's quality is rated in terms of mass, space, and light from the point of view of the pedestrian in the street. These components are: daylight and building reflectivity (measured by a Daylight Evaluation Chart), street wall length, and street wall height. The space of the street—the major street walls, which give the primary sense of containment. The new building is required to contribute to this historic and expected definition. The most significant innovation of this performance system, is the Daylight Evaluation Chart, which is entirely new to the field of American zoning. It records, in a form of spherical perspective, the amount of sky dome blocked by a proposed building as perceived by a person in the street. The diagram is kinesthetic also, in that it describes a viewer's eye sweeping or head turning a full

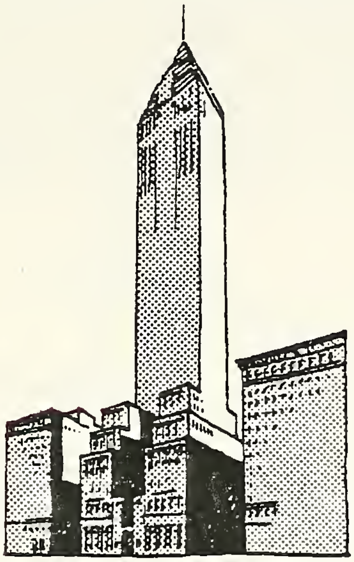


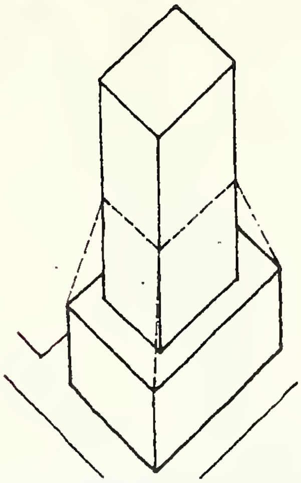
1 PRE-1916 BUILDING, 120 BROADWAY



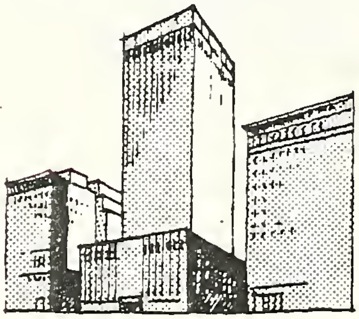


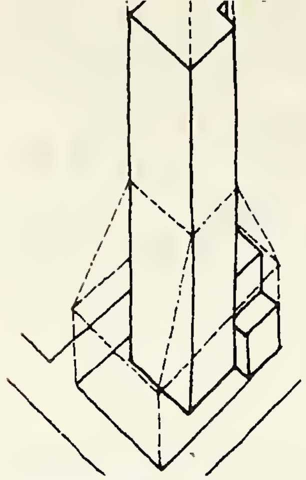
2 TYPICAL 1916 "WEDDING CAKE" BUILDING



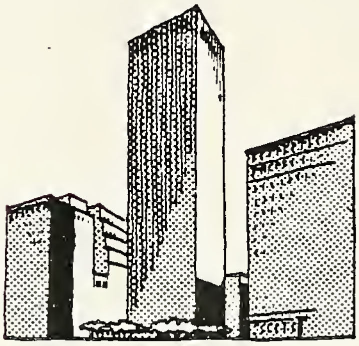


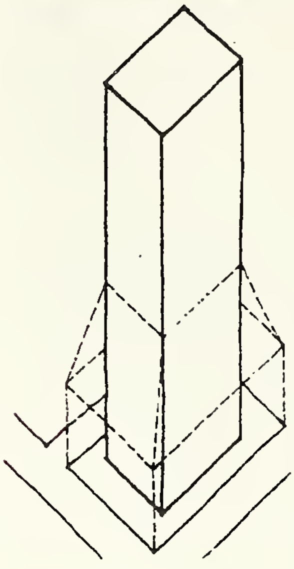
3 1961 TOWER ON BASE, FAR 15



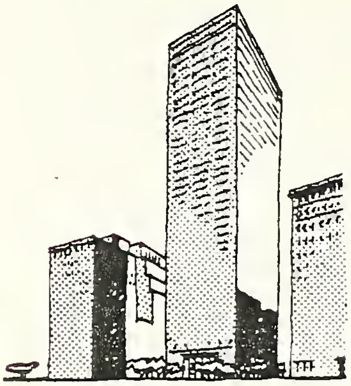


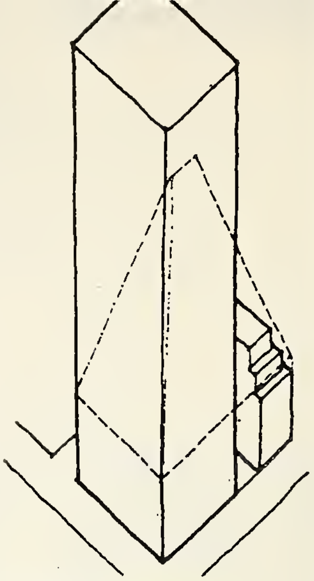
4 SEAGRAM BUILDING



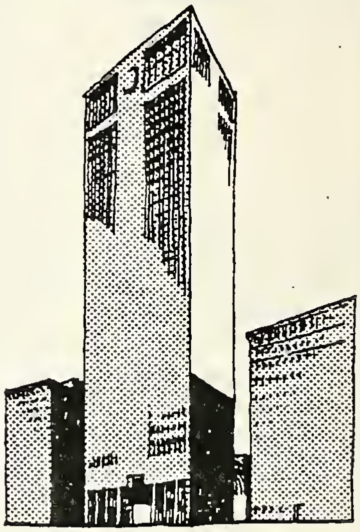


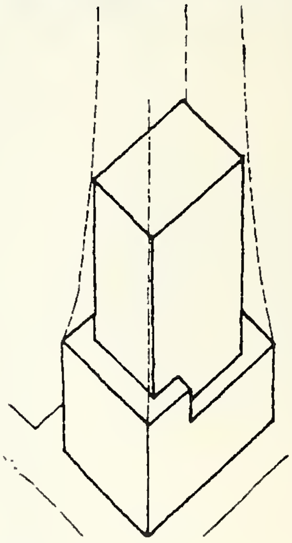
5 1961 TOWER WITH BONUSABLE PLAZA, FAR 18



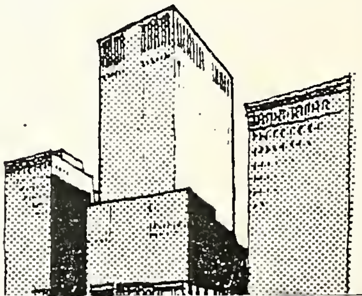


6 SPECIAL PERMIT BUILDING





7 BUILDING TO NEW DAYLIGHT CURVE TIER, FAR 15



**ation**

) degrees across the building to chart what pedestrian would actually see.

The performance system is composed of ) points, of which 85 are required for pass- . It also includes a tradeoff mechanism t allows the architect and developer to de off between themselves in achieving rall performance. As there are no metric limits on the disposition of build- bulk, there is no bias toward or against particular building shape or form. This proach properly places the design choices l decisions on the architect and developer her than on the zoning ordinance. An- er advantage of this daylight-oriented ulation is that it ensures a level of daylight- to building façades that will encourage use of daylighting for perimeter task ting as an energy-conservation measure.

**y comments**

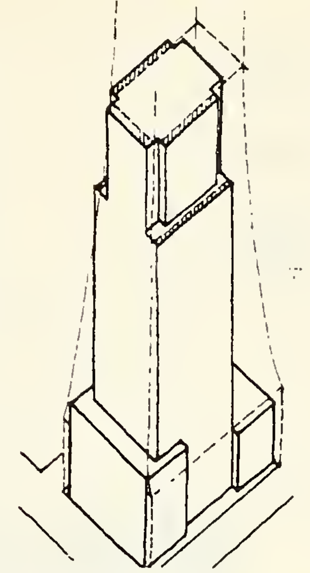
**lds:** This submission is a difficult one to mprehend, not just because there is a lot of nical information and detailed study, but ause it is, quite frankly, not well presented l is disorganized in its approach to getting oss its main ideas. But once this hurdle is r, it seems its central promise is not only in wn position of how one might look at the blem of high-rise buildings in Midtown hattan, but in its way of indicating a new ception of planning in general. Specifi- , it takes a very complicated matter and ns to look at it in a more complex way has been done in the past. It does this in laylight evaluation study by claiming to uate a building in more dimensions than plan and section, and in allowing a rating he amount of daylight that could fall into street as perceived by a pedestrian. ether or not—and I think this is debat- —it fully succeeds in that, it does set up a for a greater basis for actual perceptual uation of a plan, and also allows flexibility ting that plan. It allows freedom and in- ation in design to go back to the place re it should be, which is in the hands of ndividual architect working on the site. It recognizes, in a very important way, the ing of the edge of the street, rather than ving the creation of the type of plazas "public" amenities that in New York destroyed Sixth Avenue and made it, in amorphous.

**den:** This is an original piece of work that s some very valuable tools, but I have reservations about the degree to which path-breaking research. There was the ssion of organizing daylight zoning nd the perceptions of the pedestrian, but und really no evidence to suggest the plexities of that response vis-à-vis a single ing or a whole street of buildings. Also, was a discussion of the reflective quality aterials that would affect daylight zon- but I was not persuaded that problems such as glare and wind had been adequately thought about. There is also the bigger issue—the economic arguments—which are not at all resolved. One study a few years ago argued that the more high-rise development there is in Midtown, the more expensive it is for the city. This would contradict many of the assertions in this program, but there hasn't been any attempt to refute that earlier research. This is still a very pragmatic kind of tool, however, and still original, and for that it deserves a citation.

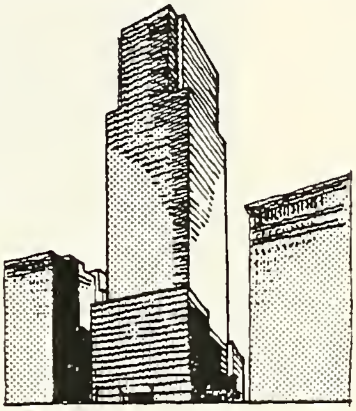
**Childs:** I am perhaps a bit more enthusiastic about this study, probably because its real advantage is in the process by which it looks at urban design matters; the process of looking at these complicated projects is more important than the specific proposals that come out of the study. It is an original idea, which is nice to see in zoning studies. It doesn't take into account many things, but doesn't pretend to. It is dealing with zoning bulk and density and a way of measuring proposals that will come before the planning commission, and in that it does break new ground and implies a more sophisticated way of looking at certain issues.

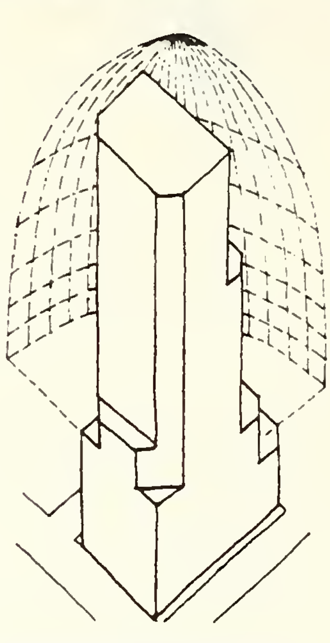
**Hayden:** One hopes that the city planning commission will now go on to commission another five pieces of research to take up some of the issues that are clearly unanswered in this specific study, but which might fall within the general brief under which it was begun. I would like to see the commission struggle with the problems of getting research to find out from the average citizen on the street just what the real effects of high-rise buildings are at any time and cumulatively over a lifetime, in both personal terms of how people respond to being constantly in such environments, and also in aggregating that kind of research to understand something more in social terms. And I would like to see the economic research done in order to understand what the taxpayers of New York are really paying for. This is an original, but somewhat narrow piece of work that does not have the status of high scientific research. There are limits in the proposal when people say "perceptual" or "performance" or "economic growth," which are unexamined assumptions that for me weaken this as research.

**Childs:** The daylight zoning proposal is more of a hope than a conclusion. The testing of it is not clear, but it opens up a new and much more sophisticated way of looking at some problems. New ground is being plowed here that can be applied to many other cities.



8 BUILDING TO NEW DAYLIGHT CURVE TIER, FAR 18





9 BUILDING TO NEW DAYLIGHT CHART TIER, FAR 18

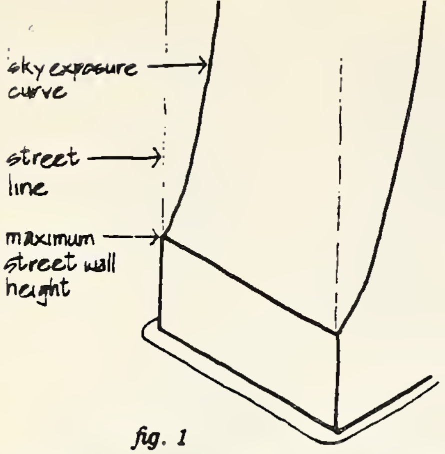


*fig. 1*

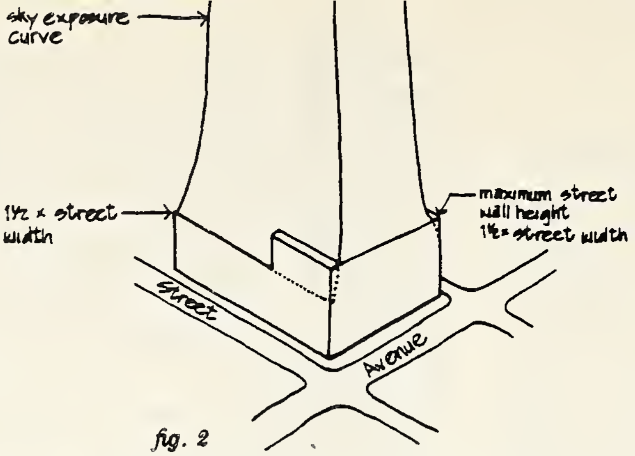


*fig. 2*

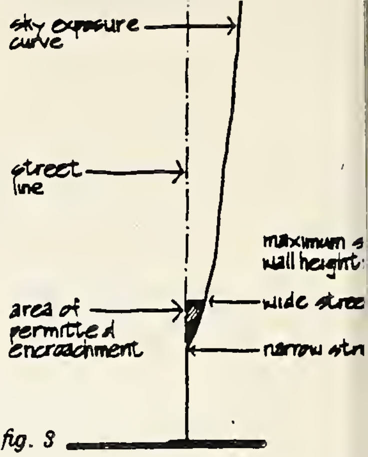
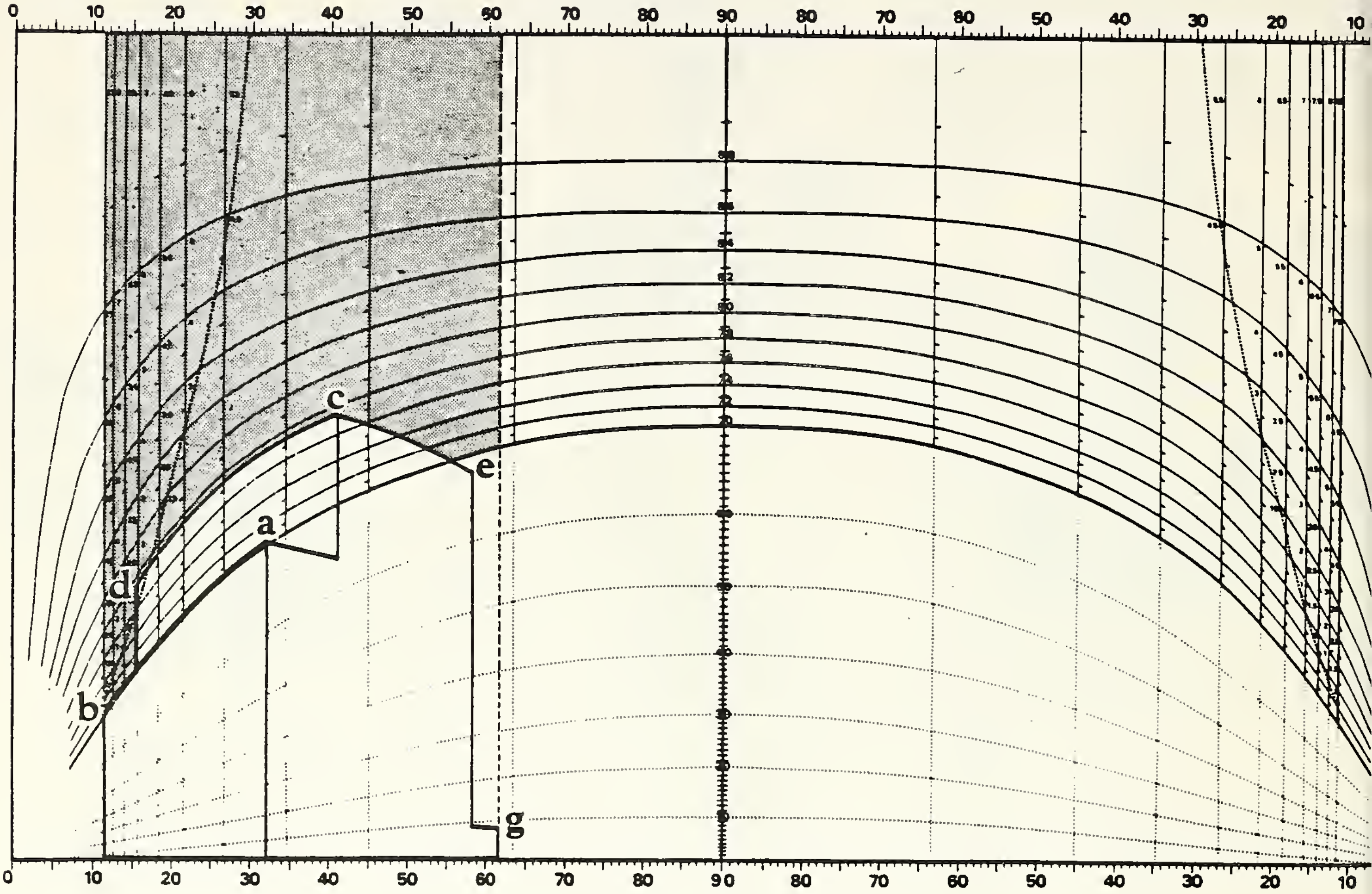
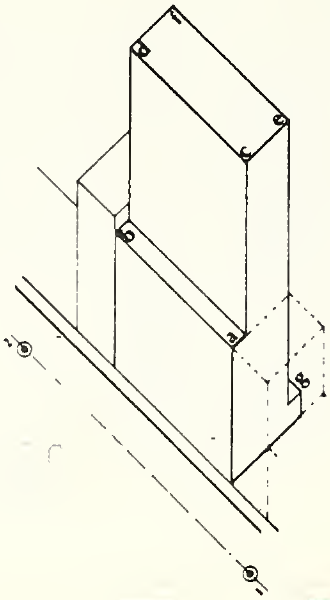


*fig. 3*



*Illustrations of Maximum Street Wall Height (top) show that before set-back is required, a building can rise uninterrupted from the street 1½ times the street's width; where wide and narrow streets intersect, the allowance for wide streets can be carried 100 ft around the corner. The Daylight Evaluation Chart (above) is based on a viewing point at which a pedestrian would be aware of the effect of a building on daylight.*



The example building should be scored as follo

AVAILABLE DAYLIGHT SQUARES

SQUARES BLOCKED TIMES VALUE
Squares above 70° blocked
Squares below 70° open
Profile Encroachment
.1 × 1.5
.25× 1 =

Total blockage

DAYLIGHT SCORE

$$\frac{89.9-20.9}{89.9} = .7675 = 76.75\%$$